

DATE ISSUED **MAY 1 1989**

2568



ORNL-6521

**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

**Environmental Sciences Division
Annual Progress Report
for Period Ending
September 30, 1988**

Environmental Sciences Division
Publication No. 3219

ChemRisk Document No. 2568

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY



This document has been approved
to the public by:

David S. Hanna 2/1/89
Technical Information Officer Date
NL Site

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy:A13 Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL-6521

Distribution Category UC-11

**ENVIRONMENTAL SCIENCES DIVISION ANNUAL PROGRESS REPORT
FOR PERIOD ENDING SEPTEMBER 30, 1988**

D. E. Reichle, Director

R. I. Van Hook, Associate Director

Section Heads

C. W. Gehrs, Environmental Toxicology

S. G. Hildebrand, Environmental Analyses

D. D. Huff, Environmental Engineering and Hydrology

S. H. Stow, Geosciences

W. Van Winkle, Ecosystem Studies

Program Managers

M. P. Farrell, Carbon Dioxide Information Analysis and Research Program

J. W. Ranney, Biomass Production Program

Environmental Sciences Division Publication No. 3219

Date Published: April 1989

**Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400**

CONTENTS

PREFACE	ix
OVERVIEW	xi
1. SECTION ACTIVITIES	1
1.1 ECOSYSTEM STUDIES	3
1.1.1 Introduction	3
1.1.2 Technical Summaries	4
In Situ Solute Transport Studies Provide Necessary Observations for Predicting the Flux of Nutrients in Watersheds	4
Decreases in Soil Exchangeable Calcium and Magnesium in Upper Slope Oak-Hickory Forests of Walker Branch Watershed Are a Result of Vegetation Uptake and Acid Deposition	6
Near-Stream and Instream Processes Regulate Nutrient Flux from a Forested Watershed During Baseflow Periods	7
Spatial Framework and Data for Walker Branch Watershed Studies Address Scale, Aggregation, and Hierarchy	8
Geographic Information System is Used to Determine Spatial Patterns of Tree Mortality and Potential Impacts on Nutrient Cycling	9
Spatial-Temporal Scaling Influences Model Predictions of Nitrogen Dynamics in Walker Branch Watershed	10
Use of the Oak Ridge NERP Ranks High Among User Facilities at ORNL	11
SO ₂ Absorption and Volatile Sulfur Emissions from Loblolly Pines Are Estimated Through Isotope Techniques	12
Study Suggests Food Web Resilience Is Not Always Directly Related to Nutrient Input and Cycling	13
Young and Old Specimens of White Oak (<i>Quercus alba</i>) Respond to Climate in the Same Way	14
Computer Models Based on Many Interacting Individual Organisms Are a Powerful New Tool in Ecological Theory	15
ORNL Initiates a Long-Term Study on Compensatory Mechanisms in Fish Populations	17
Multiple-Element Cycle Models Support Analysis of Cross-Scale Issues	18
Linkages with Nitrogen and Phosphorus Cycles Damp the Perturbation Response of a Global Carbon Cycle Model	19

1.2 ENVIRONMENTAL ANALYSES	21
1.2.1 Introduction	22
1.2.2 Technical Summaries	23
ORNL Helps DOE Prepare a NEPA Compliance Guide	23
Future Hydroelectric Development at New Dams and Diversions Is Evaluated	24
Cumulative Impacts of Hydropower Development in the Upper Ohio River Basin Are Assessed	26
Environmental Impact of the Innovative Clean Coal Technology Program Is Analyzed	27
Implications of RCRA Regulation for the Disposal of Transuranic and High-Level Waste Are Evaluated	28
Dual Regulation of High-Level Radioactive Waste Repository Is Not Necessary to Minimize Risk from the Hazardous Chemical Component of the Waste	29
Lotus Spreadsheet Model Is Created for Remedial Action Planning for Radioactively Contaminated Soil	30
The Effects that Oil Field Wastes Have on Wildlife Are Investigated	31
Sensitivity Analysis of Defense Priority Model Is Performed	32
Relationship Between Changes in Landscape Pattern and Movement of Consumers Is Established	33
Neutral Model Predicts the Spread of Disturbance Across Heterogeneous Landscapes	34
Regional Forest Productivity and Cover Are Evaluated with Nested Scales of Spectral and Biogeographical Data	35
Framework for Regional Ecological Risk Assessment Is Presented and Evaluated	36
Results of the EPA National Stream Survey Show Evidence of Acidification in the Mid-Atlantic and Southeastern United States	38
Data Management Is Provided for the ORNL Remedial Action Program	39
1.3 ENVIRONMENTAL ENGINEERING AND HYDROLOGY	40
1.3.1 Introduction	40
1.3.2 Technical Summaries	42
Tumulus Disposal Demonstration Project Is Evaluated for Low-Level Radioactive Waste Disposal	42
Performance of Concrete Silos for Low-Level Radioactive Waste Disposal Is Studied	44

Large-Scale Field Lysimeters Will Be Used to Investigate Leaching of Production Wastes Containing Depleted Uranium at the Oak Ridge Y-12 Plant	45
Interflow Rapidly Transports Stream-Deposited Chemicals Through Soils	45
Tritium and Helium Isotopes Are Used to Date Water in a Shallow Unconfined Aquifer	46
Analyses of Hydraulic Conductivity and Groundwater Chemistry Data Characterize the Shallow Aquifer Near ORNL	47
Hydraulic Conductivity Decreases with Depth in HHMS Wells in Melton Valley	48
Particle Transport in Fractured Medium Provides Evidence of Multiple Flow Paths	49
Arsenic Contamination of Groundwater Is Investigated	50
A Finite Element Model of Air Flow Through Porous Media (FEMAIR) Has Been Developed	51
An In Situ Technique Is Developed for Measuring Soil-Gas Diffusivity	53
Travel Time and Dilution of Spills to White Oak Creek Can Be Estimated with a Forecasting Model	54
1.4 ENVIRONMENTAL TOXICOLOGY	56
1.4.1 Introduction	57
1.4.2 Technical Summaries	58
Stable Carbon Isotope Discrimination ($\delta^{13}\text{C}$) in Loblolly Pine Reveals Cumulative Influence of Ozone on Water Use Efficiency Under Field Conditions	58
Fractures and Ionic Strength Are Critical Parameters in Determining the Extent of Transport of Bacteria in the Subsurface	60
Water-Use Efficiency of Tree Seedlings Is Increased by CO_2 Enrichment of the Atmosphere	61
Ectomycorrhizae and Endomycorrhizae Respond Differently to Elevated Atmospheric CO_2	62
Interpretation of Fish Response to Acidification Stress Can Differ Depending on Whether Individual or Integrated Biochemical Responses Are Considered	62
Red Spruce Growth and Photosynthesis Are Lower and Tissue Aluminum Concentrations Are Higher at High Elevations in the Great Smoky Mountains	64
Red Spruce Growth, Chlorophyll Concentrations, and Tissue Osmotic Potentials Are Lower at High Elevations in the Great Smoky Mountains	65

Response of Aquatic Ecosystems to Toxicant Stress Is Being Predicted	66
Ambient Toxicity Tests Require Nonstandard Statistical Approaches	67
The International Biospheric Model Validation Study Successfully Uses Data from Chernobyl Accident to Test Model Predictions	68
The Degree to Which Pasture Vegetation Intercepts and Retains Radioactive Materials in Rain Has Been Quantified with Mechanical Rain Simulators	70
Lakewater Chemistry in the Upper Midwest Is Not Affected Extensively by Atmospheric Deposition	71
Accumulation and Retention of ¹³⁷ Cs from ORNL Are Quantified for the Clinch River and Watts Bar Reservoir System	71
Toxicity Tests Indicate Poor Water Quality in Mitchell Branch and Potential Sources of Toxicants	73
Postclosure Remedial Actions at the S-3 Ponds May Not Improve Ecological Conditions in Bear Creek	74
Carbon Allocation Patterns in Loblolly Pine Vary with Season	75
Resilience of Aquatic Ecosystems Is Predicted with Simulation Models and Field Experiments	76
Habitat Depth Predicts Fish Size in Small Streams on the Oak Ridge Reservation	77
Sublethal Chlorine Exposure and Its Relation to Oxygen and PCB Uptake Are Studied in Rainbow Trout	78
Hepatic Enzyme Activity and Liver Condition Denote Stress in Redbreast Sunfish, <i>Lepomis macrochirus</i> , from East Fork Poplar Creek	79
1.5 GEOSCIENCES	81
1.5.1 Introduction	81
1.5.2 Technical Summaries	83
Forests in Mountainous Terrain Experience Higher Rates of Atmospheric Deposition than Low-Elevation Forests	83
Spatial Variability in Rates of Dry Deposition and in Forest Canopy Scaling Factors Can Be Determined from Analysis of Throughfall	85
Sedimentary Rock Program Evaluates Shales as Potential Hosts for High-Level Radioactive Waste Disposal	86
The Geochemical Modeling Code EQ3NR/EQ6 Is Used to Elucidate Controls on the Composition of Groundwaters in Shales	88
Availability of Aluminum and Iron to Trees Growing in Eastern North America Has Increased in the Past Two to Four Decades	89
Water Balance Data for Rogers Quarry Suggest that the Quarry Is a Minor Recharge Source to Local Groundwater	90

Radiotracer (^{203}Hg) Experiments Suggest Low Rates of Methylation of Mercury in East Fork Poplar Creek	91
Leakage of ^{90}Sr from the Impoundment at the Old Hydrofracture Facility Is Verified to Be in the Form of Fractured Flow	93
Two Types of Fracture Zones Are Identified and Characterized by Borehole Geophysical Techniques in the Waste Disposal Facilities at ORNL	94
RISC Computers Provide the Best Performance-to-Price Ratio for Contaminant Transport Simulations	95
A New Tracer Technique Is Used to Study Snowmelt Processes in Alpine Watersheds	97
Office of ORNL Is Opened in the Washington, D.C., Area	99
Fracture Analysis Is Performed on Cores from the Oak Ridge Y-12 Plant	100
Selected Shales Are Characterized Mineralogically in Support of Nuclear Waste Repository Studies	101
1.6 TECHNICAL AND ADMINISTRATIVE SUPPORT ORGANIZATION ...	103
2. PROGRAM ACTIVITIES	105
2.1 BIOMASS PRODUCTION PROGRAM	107
2.1.1 Introduction	107
2.1.2 Technical Summaries	109
Evaluating Biotechnology Research Alternatives Provides a Map for Biomass Research Initiatives with Achievable Goals	109
Successional Vegetation Offers an Economical Alternative for Energy Feedstock Production	110
Photosynthetic Rates, Pigment Concentrations, and Nitrate Reductase Activity Are Sensitive Bioindicators of Sycamore Response to Nitrogen Fertilization	112
Research of the Energy Poplar Consortium Is Given Direction	113
Economic Energy Potential of Biomass Is Significantly Improved with New Biomass Energy Crops	114
2.2 CARBON DIOXIDE INFORMATION ANALYSIS AND RESEARCH PROGRAM	115
2.2.1 Introduction	115
2.2.2 Technical Summaries	119
Global Reforestation Could Play a Significant Role in Addressing the CO_2 Problem	119
Simulations Delineate the Potential Response of Pacific Northwest Forests to Increasing Temperatures	120

A Warmer Climate Will Alter the Role of Peatlands, Tundra, and Boreal Ecosystems in the Global Carbon Cycle	120
Ocean Ventilation Rates Changed over the Last 7000 Years Based on ¹⁴ C Variations in the Atmosphere and Oceans	121
Oceanic Uptake of CO ₂ in the Atlantic Is Modeled	122
A Circulation Model of the Oceanic Carbon Cycle Is Developed	124
Preliminary Development of a Global Coastal Hazards Data Base Is Completed	126
Interactions Between CO ₂ and Climate Have Unknown Consequences for Agriculture	127
Carbon Dioxide Information Analysis Center Provides Numeric Data and Computer Model Packages	128
3. LISTS	131
3.1 AWARDS AND HONORS	133
3.2 SIGNIFICANT ACCOMPLISHMENTS	135
3.3 CONFERENCES ORGANIZED OR CHAIRED	137
3.4 RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS	139
3.5 TECHNOLOGY TRANSFER	154
3.6 EDUCATION PROGRAMS	157
3.7 AFFIRMATIVE ACTION	162
3.8 SEMINAR PROGRAM	164
3.9 VISITORS HOSTED	165
3.10 PUBLICATIONS	167
3.11 PRESENTATIONS	193
3.12 PROFESSIONAL ACTIVITIES	217
4. ORGANIZATION CHART	253
ABBREVIATIONS	257

PREFACE

This progress report summarizes the research and development activities conducted in the Environmental Sciences Division of Oak Ridge National Laboratory during the period October 1, 1987, through September 30, 1988. The report is structured to provide descriptions of current activities and accomplishments in each of the Division's major organizational units. Following the accounts of section activities and program activities is a section devoted to lists of information necessary to convey the scope of the work in the Division.

OVERVIEW

The Environmental Sciences Division (ESD) of Oak Ridge National Laboratory (ORNL) conducts research on the environmental aspects of existing and emerging energy systems and applies this information to ensure that technology development and energy use are consistent with national environmental health and safety goals. ESD performs basic and applied research, environmental assessments, environmental engineering and demonstration, technology and operational support, and program management for the U.S. Department of Energy (DOE), other federal and state agencies, and industry. ESD works collaboratively with a number of federal agencies, universities, and the private sector in accomplishing its programs and hosts a significant number of visiting investigators from universities, industry, and other federal agencies. Offering an interdisciplinary resource of staff and facilities to address complex environmental problems, the Division is currently providing technical leadership for major environmental issues of national concern: (1) acidic deposition and related environmental effects, (2) the global carbon cycle and the effects of increasing concentrations of atmospheric CO₂ and the resulting climatic changes to ecosystems and natural and physical resources, (3) hazardous chemical and radioactive waste disposal research and development, and (4) development of commercial biomass energy production systems. In addition, ESD manages DOE's Carbon Dioxide Information Center and a National Environmental Research Park (NERP). This progress report outlines ESD's accomplishments in these and other areas in FY 1988.

Research in the Ecosystem Studies Section is directed at quantifying how terrestrial and aquatic ecosystems function and respond to the stresses of anthropogenic activities. The Section has primary responsibility for the Walker Branch Watershed, which has been used for the past 20 years to study ecosystem dynamics and mineral cycling in forested landscapes. In addition, the Section is responsible for management of the Oak Ridge NERP and serves as the Division liaison with the Tennessee Valley Authority Ecology Program.

The Environmental Analyses Section develops theory and methods, analytical tools, and numeric data bases to evaluate environmental problems and issues. The Section staff conduct research and interdisciplinary assessments of environmental issues at spatial scales ranging from the individual site to the regional landscape and the globe. The Section also provides technical assistance for the development of policy on compliance with environmental regulations. Section staff are making major contributions to the 1990 National Acid Precipitation Assessment Program assessment on acidic precipitation.

The Environmental Engineering and Hydrology Section conducts research, development, and demonstration projects that involve advanced waste disposal methods, surface and groundwater hydrology, contaminant transport, and a variety of simulation models. A significant component of the Section's activities is concerned with the Oak Ridge Reservation. The Section focuses on activities that begin with potential sources of contaminants and the engineering methods for their control and then traces the effects that various hydrologic and geochemical processes have on the subsequent transport and fate of residuals. In the process of stabilizing old sites and helping to design new, more effective disposal systems, the underlying science is considered the most important factor.

The Environmental Toxicology Section is involved in basic and applied research designed to elucidate the mechanisms through which contaminants affect biological systems and the ways in which receiving systems affect the availability and distribution of materials to which they are exposed. Research is conducted from the subcellular and biochemical level to the system level with experimental, observational, and simulation studies. Section staff are involved in development of biomarkers and other new approaches to detecting chemical contamination, elucidation of the role of microbial populations in organic materials transport and transformation, and understanding the bases of plant response to physiological stresses including O₃, acid rain, and other oxidants.

Staff of the Geosciences Section conduct basic and applied research directed toward an understanding of the physical and chemical mechanisms that control the movement of material through the lithosphere and atmosphere. Specific projects are carried out in the areas of geochemistry, geology, geophysics, atmospheric science, soils science, and oceanography and involve close interactions with scientists conducting biologic and hydrologic transport studies. The scope of the activities includes field characterization and testing, laboratory experiments, and mathematical and computer modeling. The Section strives to maintain a proper balance between basic and applied studies, and the common theme that relates to the vast majority of the activities is associated with the study of waste materials and by-products from energy production.

The Biomass Production Program (BPP) is a 10-year-old interdisciplinary program of research on plant growth. The BPP includes four divisions at ORNL, more than 25 other institutions (most of which are land grant universities), and several consulting scientists across the country. The BPP mission is to improve the productivity and cost efficiency of specialized energy crops destined for conversion to liquid fuel. ESD manages the BPP for the Biofuels and Municipal Waste Technology Division, a part of the Conservation and Renewables activities of DOE. The BPP has three major components within ORNL: Herbaceous Energy Crops; Short Rotation Woody Crops; and in-house research focused on physiology, nutrient cycling, economics, and data management/synthesis. With the exception of rapeseed for diesel oil production, all energy crops under study are primarily lignocellulosic; that is, they are being developed for organic matter production (cellulose, hemicellulose, lignin, and nonstructural carbohydrates) rather than for oil, special carbohydrates, or protein.

The Carbon Dioxide Research Program administers the Carbon Dioxide Information and Analysis Center (CDIAC), the Carbon Cycle Research Program, and the resource analysis work for the DOE Carbon Dioxide Research Division. ESD has the technical and managerial responsibility for planning and meeting DOE goals in these areas and does so with an in-house technical staff of 10 scientists supported by a group of 20 key university collaborators. The major focus of the program is on maintaining the best quality global data bases and models, analysis of the linkages and feedbacks between the principal components of the global carbon cycle (atmosphere-biosphere-oceans), and evaluation of the impacts of increased atmospheric CO₂ and global warming on the earth's major resources (forests, agriculture, fisheries, coastal zones, and water).

ORNL
MASTER COPY 2568

DATE ISSUED APR 22 1987

ORNL-6327

ornl

**OAK RIDGE
NATIONAL
LABORATORY**

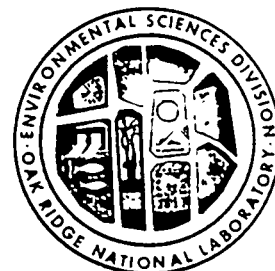
MARTIN MARIETTA

**Environmental Sciences Division
Annual Progress Report
for Period Ending September 30, 1986**

**Environmental Sciences Division
Publication No. 2801**

This document has been approved for release
to the public by:

Donna E. Hannon 2/9/96
Technical Information Officer Date
ORNL Site



ChemRisk Document No. 2568

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A10 Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**ENVIRONMENTAL SCIENCES DIVISION
ANNUAL PROGRESS REPORT
for Period Ending September 30, 1986**

D. E. Reichle, Director

SECTION HEADS

N. H. Cutshall	Earth Sciences
C. W. Gehrs	Aquatic Ecology
S. G. Hildebrand	Environmental Analyses
R. I. Van Hook	Terrestrial Ecology

PROGRAM MANAGERS

C. C. Coutant	Carbon Dioxide Research Program
M. F. Farrell	Carbon Dioxide Information Center
J. W. Ranney	Biomass Production Program

PROJECT DEVELOPMENT

S. I. Auerbach, Senior Staff Advisor
T. Tamura, Senior Research Advisor

Environmental Sciences Division Publication No. 2801

Date Published: April 1987

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

ADMINISTRATIVE SUPPORT

**R. E. Canning
A. B. McDaniel
S. Y. Porter
R. O. Wadlington
D. M. Wiffen**

**SAFETY, ENVIRONMENTAL PROTECTION,
RADIATION CONTROL, QUALITY ASSURANCE**

R. K. McConathy

WORD PROCESSING CENTER

**D. D. Rhew
G. R. Carter
D. H. Deaton
P. G. Epperson
C. A. Kappelmann**

FINANCE OFFICE

T. T. Vann

EDITORIAL OFFICE

**D. S. Barnes
A. L. Ragan
N. E. Tarr**

**Publications Section
Information Resources Organization**

GRAPHIC ARTS

**J. E. Holbrook
R. R. Adams
R. E. Booker**

**Graphics Section
Information Resources Organization**

ABSTRACT

REICHLE, D. E., et al. 1987. Environmental Sciences Division
Annual Progress Report for Period Ending September 30, 1986. ORNL-
6327. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The Environmental Sciences Division (ESD) of Oak Ridge National Laboratory (ORNL) conducts research on the environmental aspects of existing and emerging energy systems and applies this information to ensure that technology development and energy use are consistent with national environmental health and safety goals. ESD performs basic and applied research, environmental assessments, environmental engineering and demonstration, technology and operational support, and program management for the U. S. Department of Energy (DOE), other federal and state agencies, and industry. ESD works collaboratively with a number of federal agencies, universities, and the private sector in accomplishing its programs. The Division offers an interdisciplinary resource of staff and facilities to address complex environmental problems. ESD is currently providing technical leadership for major environmental issues of national concern: (1) acidic deposition and related environmental effects, (2) the global carbon cycle and the effects of increasing concentrations of atmospheric CO₂ and the resulting climatic changes on ecosystems and natural and physical resources, (3) hazardous chemical and radioactive waste disposal R&D, and (4) development of commercial biomass energy production systems. In addition, ESD also manages DOE's Carbon Dioxide Information Center. This progress report outlines ESD's accomplishments in these and other areas in FY 1986.

In the Aquatic Ecology Section, research continues to focus on developing an understanding of how freshwater ecosystems affect the transport and fate of materials and respond to these materials. Activities related to ecosystem recovery and resiliency were substantially expanded during this fiscal year and have become a major theme of the Section's efforts. The Chernobyl accident brought renewed interest and activity in radioecology.

The Earth Sciences Section is continuing its major involvement in ORNL's remedial action programs. In addition, growth and diversification of geoscience investigations in support of the Y-12 Plant are continuing. Other projects include the implementation of an advanced geochemical transport code on a hypercube parallel computer, characterization of the history of heavy metal contamination of the sediments of Pearl Harbor, Hawaii, and collaborative testing of the Environmental Protection Agency's Toxicity Characteristic Leaching Procedure.

The Environmental Analyses Section performs quantitative and qualitative assessments of the impacts of human activities on the environment. Highlights for FY 1986 include continued technical support to the National Acid Precipitation Assessment Program environmental surveys; analysis of how environmental regulations may affect DOE; data management for, and technical analyses of, hazardous waste remedial actions at ORNL; risk assessment techniques for marine systems; and evaluation of remote sensing techniques. Technical analyses in support of the National Environmental Policy Act are continuing.

The Terrestrial Ecology Section conducts basic and applied research in support of energy technology development and has, as a major objective, development of a more thorough understanding of the basic processes that govern the transport and effects of materials in terrestrial ecosystems. Highlighted this year are recent advances in physiological ecology, biogeochemical cycling, and ecosystem dynamics, as these themes relate to national environmental issues.

Activities of the Biomass Production Program consist of technical management of the Short Rotation Woody Crops Program, the Herbaceous Energy Crops Program, and environmental and economic analyses in support of these two programs. In the Short Rotation Woody Crops Program, tree- and stand-level ecophysiological growth modeling of wood energy crops has been initiated across the United States to define the most important traits for genetic improvement of selected "model" species. In the Herbaceous Energy Crops Program, screening efforts associated with herbaceous lignocellulosic and oil-seed-producing species are in the early stages of identifying and selecting plants for their maximum energy production, which is often inversely related to their maximum food value. Wood and herbaceous lignocellulosic energy crops will be the renewable raw feedstock for producing alternative liquid and gaseous fuels using conversion technologies.

The Carbon Dioxide Research Program continues to administer DOE's Global Carbon Cycle Program. It also oversees ORNL's research for DOE's Carbon Dioxide Research Division on the carbon cycle and the biological effects of increased atmospheric CO₂. Intensive program planning followed the publication in 1985 of a state-of-the-art report on atmospheric CO₂ and the global carbon cycle. Notable research results include the acquisition of winter data on the CO₂ flux from the North Pacific Ocean, which has caused a substantial revision of the models of global CO₂ sources and sinks, and an indication, from satellite imagery and modeling, of the importance of climate acting on the terrestrial biosphere in regulating seasonal and interannual variations in atmospheric CO₂.

The objective of the Carbon Dioxide Information Center (CDIC) is to compile, evaluate, and distribute CO₂-related information in support of DOE's Carbon Dioxide Research Division. To accomplish this objective, CDIC identifies researchers' needs for data and computer hardware, software, and languages; obtains, evaluates, and ensures the quality of information; and works with other national and international data centers as well as individual researchers to promote and facilitate the exchange of data. CDIC's functions include information analysis as well as information distribution activities. Highlights for FY 1986 include the compilation of four numeric data packages, the development of methods for studying the effects of climate change on world resources, and the development of a research plan for using computer-generated sound to analyze multivariate data.

Contents

ABSTRACT	iii
ENVIRONMENTAL SCIENCES DIVISION AWARDS AND HONORS	xi

PART I. ENVIRONMENTAL SCIENCES DIVISION SECTIONS

1. AQUATIC ECOLOGY	1
Introduction	2
The Use of Chernobyl Fallout to Test Model Predictions of the Transfer of Radioiodine from Air to Vegetation to Milk	3
The Use of Chernobyl Fallout to Quantify the Transfer of Submicron Aerosols from Rain to Vegetation and to Test Natural ^7Be as an Environmental Tracer	4
Radionuclides as Tracers to Quantify the Relationship Between Contaminant Input, Deposition, and Accumulation in Aquatic Environments	6
Ecological Effects of Acidification on Low-Order Woodland Streams	6
Preliminary Screening of Radionuclides in White Oak Lake and Environs for Remedial Action Scenarios	8
Bioaccumulation Monitoring in the Y-12 Biological Monitoring and Abatement Program	8
Nutrient Cycling, Ecosystem Structure, and Ecosystem Stability	9
Increasing Microalgal Lipid Yields Through Flow Cytometry	11
Beryllium-7 Sorption Kinetics and Water Column Residence Time in River-Reservoir Systems	12
Interfacing Toxicity Tests with Chemical Analyses to Identify Critical Process Steps in Wastewater Treatment Facilities	12
Evaluating Mixed-Function Oxidase and Electron Transport Enzymes in Fish as Indicators of Environmental Pollution	13
2. EARTH SCIENCES	15
Introduction	15
Dry Deposition of Nitrate to a Forest	16
Collaborative Testing of the Toxicity Characteristic Leaching Procedure	17

Characterization of and Remedial Action for ORNL Waste Impoundments	17
Mercury in Ambient Air at the Y-12 Plant	18
Nature of pH Variations in Rogers Quarry	18
Determination of Soil Contaminant Profiles for Y-12 Facilities	19
Immobilization of Buried Transuranic Waste with Acrylamide Grout	19
Radionuclides as Tracers in Coastal Zones	20
Sedimentary Rock Program	21
Nuclear Regulatory Commission High-Level Nuclear Waste Program	21
The Hydrofracture Program	22
Hydrostatic Head Monitoring Stations	23
Hypercube Parallel Computers in Environmental Research: An Example from Contaminant Transport Simulation	23
Solid Waste Storage Area 6 Characterization Studies	24
Solid Waste Storage Area 4 Data Package	24
Trace Metal Levels in Pearl Harbor Sediments	25
Forest-Clearing Experiment	25
Development of Waste Disposal Technologies	26
"Bathtubbing" Trenches	27
Modeling Groundwater Flow and Contaminant Transport	27
References	28
3. ENVIRONMENTAL ANALYSES SECTION	30
Introduction	30
Scientific and Technical Analyses of New Rule Making	32
Cumulative Impacts to Trout of Basinwide Multiple Hydropower Development	33
Environmental Impacts of Low-Flying Bomber Aircraft Along Proposed Air Force Training Routes	33
Interpreting Forest Biome Productivity Utilizing Nested Scales of Image Resolution and Biogeographical Analysis	34
Application of Lake Survey Data to Evaluate the Role of Acidic Deposition in Determining the Chemical Status of Lakes	35
Direct-Delayed Response Project	36
Data Management and Analysis for the National Stream Survey	37

Numeric Data Base Established for the Remedial Action Program	37
Comparative Toxicology for Marine Fish and Crustaceans	38
Intruder Scenarios for the Oak Ridge Low-Level Waste Burial Grounds	39
Strategy and Closure Criteria Development for the ORNL Remedial Action Program: Regulatory Interface	40
References	41
4. TERRESTRIAL ECOLOGY	42
Introduction	42
Physiological Ecology	45
Stress Physiology in Terrestrial Vegetation: The Physiological Site of Ethylene Action in Carbon Dioxide Assimilation	45
Symbiotic Activity in Woody Plants Stimulated by Atmospheric Carbon Dioxide Enrichment	45
Biogeochemical Cycling	47
Preliminary Evaluation of Chernobyl-Derived Radioactivity Measured in Oak Ridge May 7 to June 3, 1986	47
Subsurface Transport Project	49
Radiosulfur Cycling Research at Walker Branch Watershed	50
Integrated Forest Study	51
Ecosystem Dynamics	52
National Environmental Research Park	52
Climatic Change in the Amazon Region	53
Multiple Nutrient Limitations in Ecological Processes	54
 PART II. ENVIRONMENTAL SCIENCES DIVISION PROGRAMS	
5. BIOMASS PRODUCTION	55
Introduction	55
Growth Modeling of Wood Energy Crops	56
The Tree-Level Ecophysiological Model	56
The Stand-Level Ecophysiological Model	56
Integration of Tree- and Stand-Level Models	59
Improvement of Herbaceous Lignocellulosic Energy Crops	59
Improvement of Oilseed Energy Crops	62
References	63

6. CARBON DIOXIDE RESEARCH PROGRAM	64
Introduction	64
Extramural Research	65
Development of a Three-Dimensional Model of the Natural Carbon Cycle in the Oceans and Its Perturbation by Anthropogenic CO ₂	65
The Effect of Pressure on Aragonite Dissolution Rates in Seawater	66
Assessment of Seasonal and Geographic Variability in CO ₂ Sinks and Sources in the Ocean	67
The Role of Tropical Forests in the Global Carbon Cycle	68
Comparison of Pre- and Post-Atomic-Bomb Radiocarbon in Soils	68
The Role of CaCO ₃ Compensation in the Glacial-to-Interglacial Change in Atmospheric CO ₂ Content	69
The Role of Ocean CO ₂ Sources and Sinks in the Southern Hemisphere: Data Analysis and Modeling	69
Increase of Total CO ₂ in the World Oceans	70
Study of CO ₂ Source and Sink Distributions with a Three-Dimensional Model	71
Intramural Research	71
Sensitivity and Uncertainty Analysis of a Model of Forest Development	71
Modeling the Seasonality of Terrestrial Contributions to Atmospheric CO ₂	72
CO ₂ Enrichment and Mineral Nutrition of White Oaks	72
Changing Carbon Storage and Carbon:Nitrogen Ratios in Cultivated Soil	73
Seasonal Variability of pCO ₂ in the Northern Atlantic Surface Water	74
References	75
7. CARBON DIOXIDE INFORMATION CENTER	76
Introduction	76
Data and Information Analyses	77
Numeric Data and Computer Model Packages	77
Global Climate—Resource Studies	77
Music Analysis	79
Climatic Indices	81
Information Distribution	81
Request and Response Records Systems	81
Bibliographic Information System	82
Communications	82
Networking	82
Special Projects	83
People's Republic of China	83
Resource Analysis Plan	83
Coordination, Control, and Communication	83
Sea Level Rise	84
References	84

PART III. EXTRAMURAL ACTIVITIES

8. EDUCATION	85
Seminar Program	85
Undergraduate Education Program	88
Graduate Education Program	88
Faculty Program	89
High School Science Teachers Program	92
9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS	93
10. CONFERENCES ORGANIZED OR CHAIRED	106
11. SCIENTIFIC GUESTS	107
12. VISITORS (TOURS AND REGISTERED GUESTS)	110
13. TECHNOLOGY TRANSFER	112

PART IV. APPENDICES

PUBLICATIONS, PRESENTATIONS, THESES, AND PROFESSIONAL ACTIVITIES...	114
Publications	114
Presentations	132
Theses	147
Professional Activities	147
ORGANIZATION CHART	185

ENVIRONMENTAL SCIENCES DIVISION AWARDS AND HONORS

C. C. COUTANT

Martin Marietta Energy Systems, Inc., Publication Award, 1986.

D. L. DeANGELIS

Martin Marietta Energy Systems, Inc., Publication Award, 1986.

J. W. ELWOOD

Fellow, American Association for the Advancement of Science.

M. P. FARRELL

Martin Marietta Energy Systems, Inc., Operational Performance Award, 1986.

Miami University, Institute of Environmental Sciences, Award of Distinction, 1986.

R. H. GARDNER

Environmental Sciences Division Scientific Achievement Award, 1985.

C. W. GEHRS

Fellow, American Association for the Advancement of Science.

D. W. JOHNSON

Martin Marietta Energy Systems, Inc., Technical Achievement Award, 1986.

S. E. LINDBERG

Martin Marietta Energy Systems, Inc., Technical Achievement Award, 1986.

J. F. McBRAYER

American Society for Surface Mining and Reclamation, Appreciation Award, 1986.

S. B. McLAUGHLIN

Martin Marietta Energy Systems, Inc., Publication Award, 1986.

W. M. POST

Martin Marietta Energy Systems, Inc., Publication Award, 1986.

S. F. RAILSBACK

Professional Engineer's License, Civil Engineering, State of California, 1986.

V. R. TOLBERT

American Society for Surface Mining and Reclamation, Appreciation Award, 1986.

J. R. TRABALKA

U.S. Department of Energy Headquarters Commendation, 1986.

**ORNL
MASTER COPY**

DATE ISSUED APR 22 1987

ORNL-6327

#2568

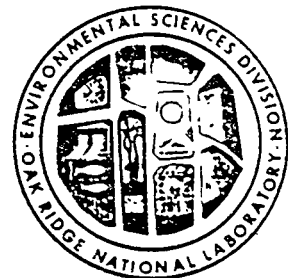
ornl

**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

**Environmental Sciences Division
Annual Progress Report
for Period Ending September 30, 1986**

**Environmental Sciences Division
Publication No. 2801**



MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

#2568

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A10 Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**ENVIRONMENTAL SCIENCES DIVISION
ANNUAL PROGRESS REPORT
for Period Ending September 30, 1986**

D. E. Reichle, Director

SECTION HEADS

N. H. Cutshall	Earth Sciences
C. W. Gehrs	Aquatic Ecology
S. G. Hildebrand	Environmental Analyses
R. I. Van Hook	Terrestrial Ecology

PROGRAM MANAGERS

C. C. Coutant	Carbon Dioxide Research Program
M. F. Farrell	Carbon Dioxide Information Center
J. W. Ranney	Biomass Production Program

PROJECT DEVELOPMENT

**S. I. Auerbach, Senior Staff Advisor
T. Tamura, Senior Research Advisor**

Environmental Sciences Division Publication No. 2801

Date Published: April 1987

**OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400**

ADMINISTRATIVE SUPPORT

**R. E. Canning
A. B. McDaniel
S. Y. Porter
R. O. Wadlington
D. M. Wiffen**

**SAFETY, ENVIRONMENTAL PROTECTION,
RADIATION CONTROL, QUALITY ASSURANCE**

R. K. McConathy

WORD PROCESSING CENTER

**D. D. Rhew
G. R. Carter
D. H. Deaton
P. G. Epperson
C. A. Kappelmann**

FINANCE OFFICE

T. T. Vann

EDITORIAL OFFICE

**D. S. Barnes
A. L. Ragan
N. E. Tarr**

**Publications Section
Information Resources Organization**

GRAPHIC ARTS

**J. E. Holbrook
R. R. Adams
R. E. Booker**

**Graphics Section
Information Resources Organization**

ABSTRACT

REICHLE, D. E., et al. 1987. Environmental Sciences Division
Annual Progress Report for Period Ending September 30, 1986. ORNL-
6327. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The Environmental Sciences Division (ESD) of Oak Ridge National Laboratory (ORNL) conducts research on the environmental aspects of existing and emerging energy systems and applies this information to ensure that technology development and energy use are consistent with national environmental health and safety goals. ESD performs basic and applied research, environmental assessments, environmental engineering and demonstration, technology and operational support, and program management for the U. S. Department of Energy (DOE), other federal and state agencies, and industry. ESD works collaboratively with a number of federal agencies, universities, and the private sector in accomplishing its programs. The Division offers an interdisciplinary resource of staff and facilities to address complex environmental problems. ESD is currently providing technical leadership for major environmental issues of national concern: (1) acidic deposition and related environmental effects, (2) the global carbon cycle and the effects of increasing concentrations of atmospheric CO₂ and the resulting climatic changes on ecosystems and natural and physical resources, (3) hazardous chemical and radioactive waste disposal R&D, and (4) development of commercial biomass energy production systems. In addition, ESD also manages DOE's Carbon Dioxide Information Center. This progress report outlines ESD's accomplishments in these and other areas in FY 1986.

In the Aquatic Ecology Section, research continues to focus on developing an understanding of how freshwater ecosystems affect the transport and fate of materials and respond to these materials. Activities related to ecosystem recovery and resiliency were substantially expanded during this fiscal year and have become a major theme of the Section's efforts. The Chernobyl accident brought renewed interest and activity in radioecology.

The Earth Sciences Section is continuing its major involvement in ORNL's remedial action programs. In addition, growth and diversification of geoscience investigations in support of the Y-12 Plant are continuing. Other projects include the implementation of an advanced geochemical transport code on a hypercube parallel computer, characterization of the history of heavy metal contamination of the sediments of Pearl Harbor, Hawaii, and collaborative testing of the Environmental Protection Agency's Toxicity Characteristic Leaching Procedure.

The Environmental Analyses Section performs quantitative and qualitative assessments of the impacts of human activities on the environment. Highlights for FY 1986 include continued technical support to the National Acid Precipitation Assessment Program environmental surveys; analysis of how environmental regulations may affect DOE; data management for, and technical analyses of, hazardous waste remedial actions at ORNL; risk assessment techniques for marine systems; and evaluation of remote sensing techniques. Technical analyses in support of the National Environmental Policy Act are continuing.

The Terrestrial Ecology Section conducts basic and applied research in support of energy technology development and has, as a major objective, development of a more thorough understanding of the basic processes that govern the transport and effects of materials in terrestrial ecosystems. Highlighted this year are recent advances in physiological ecology, biogeochemical cycling, and ecosystem dynamics, as these themes relate to national environmental issues.

Activities of the Biomass Production Program consist of technical management of the Short Rotation Woody Crops Program, the Herbaceous Energy Crops Program, and environmental and economic analyses in support of these two programs. In the Short Rotation Woody Crops Program, tree- and stand-level ecophysiological growth modeling of wood energy crops has been initiated across the United States to define the most important traits for genetic improvement of selected "model" species. In the Herbaceous Energy Crops Program, screening efforts associated with herbaceous lignocellulosic and oil-seed-producing species are in the early stages of identifying and selecting plants for their maximum energy production, which is often inversely related to their maximum food value. Wood and herbaceous lignocellulosic energy crops will be the renewable raw feedstock for producing alternative liquid and gaseous fuels using conversion technologies.

The Carbon Dioxide Research Program continues to administer DOE's Global Carbon Cycle Program. It also oversees ORNL's research for DOE's Carbon Dioxide Research Division on the carbon cycle and the biological effects of increased atmospheric CO₂. Intensive program planning followed the publication in 1985 of a state-of-the-art report on atmospheric CO₂ and the global carbon cycle. Notable research results include the acquisition of winter data on the CO₂ flux from the North Pacific Ocean, which has caused a substantial revision of the models of global CO₂ sources and sinks, and an indication, from satellite imagery and modeling, of the importance of climate acting on the terrestrial biosphere in regulating seasonal and interannual variations in atmospheric CO₂.

The objective of the Carbon Dioxide Information Center (CDIC) is to compile, evaluate, and distribute CO₂-related information in support of DOE's Carbon Dioxide Research Division. To accomplish this objective, CDIC identifies researchers' needs for data and computer hardware, software, and languages; obtains, evaluates, and ensures the quality of information; and works with other national and international data centers as well as individual researchers to promote and facilitate the exchange of data. CDIC's functions include information analysis as well as information distribution activities. Highlights for FY 1986 include the compilation of four numeric data packages, the development of methods for studying the effects of climate change on world resources, and the development of a research plan for using computer-generated sound to analyze multivariate data.

Contents

ABSTRACT	iii
----------------	-----

ENVIRONMENTAL SCIENCES DIVISION AWARDS AND HONORS	xi
---	----

PART I. ENVIRONMENTAL SCIENCES DIVISION SECTIONS

1. AQUATIC ECOLOGY	1
Introduction	2
The Use of Chernobyl Fallout to Test Model Predictions of the Transfer of Radioiodine from Air to Vegetation to Milk	3
The Use of Chernobyl Fallout to Quantify the Transfer of Submicron Aerosols from Rain to Vegetation and to Test Natural ^7Be as an Environmental Tracer	4
Radionuclides as Tracers to Quantify the Relationship Between Contaminant Input, Deposition, and Accumulation in Aquatic Environments	6
Ecological Effects of Acidification on Low-Order Woodland Streams	6
Preliminary Screening of Radionuclides in White Oak Lake and Environs for Remedial Action Scenarios	8
Bioaccumulation Monitoring in the Y-12 Biological Monitoring and Abatement Program	8
Nutrient Cycling, Ecosystem Structure, and Ecosystem Stability	9
Increasing Microalgal Lipid Yields Through Flow Cytometry	11
Beryllium-7 Sorption Kinetics and Water Column Residence Time in River-Reservoir Systems	12
Interfacing Toxicity Tests with Chemical Analyses to Identify Critical Process Steps in Wastewater Treatment Facilities	12
Evaluating Mixed-Function Oxidase and Electron Transport Enzymes in Fish as Indicators of Environmental Pollution	13
2. EARTH SCIENCES	15
Introduction	15
Dry Deposition of Nitrate to a Forest	16
Collaborative Testing of the Toxicity Characteristic Leaching Procedure	17

Characterization of and Remedial Action for ORNL Waste Impoundments	17
Mercury in Ambient Air at the Y-12 Plant	18
Nature of pH Variations in Rogers Quarry	18
Determination of Soil Contaminant Profiles for Y-12 Facilities	19
Immobilization of Buried Transuranic Waste with Acrylamide Grout	19
Radionuclides as Tracers in Coastal Zones	20
Sedimentary Rock Program	21
Nuclear Regulatory Commission High-Level Nuclear Waste Program	21
The Hydrofracture Program	22
Hydrostatic Head Monitoring Stations	23
Hypercube Parallel Computers in Environmental Research: An Example from Contaminant Transport Simulation	23
Solid Waste Storage Area 6 Characterization Studies	24
Solid Waste Storage Area 4 Data Package	24
Trace Metal Levels in Pearl Harbor Sediments	25
Forest-Clearing Experiment	25
Development of Waste Disposal Technologies	26
"Bathtubbing" Trenches	27
Modeling Groundwater Flow and Contaminant Transport	27
References	28
3. ENVIRONMENTAL ANALYSES SECTION	30
Introduction	30
Scientific and Technical Analyses of New Rule Making	32
Cumulative Impacts to Trout of Basinwide Multiple Hydropower Development	33
Environmental Impacts of Low-Flying Bomber Aircraft Along Proposed Air Force Training Routes	33
Interpreting Forest Biome Productivity Utilizing Nested Scales of Image Resolution and Biogeographical Analysis	34
Application of Lake Survey Data to Evaluate the Role of Acidic Deposition in Determining the Chemical Status of Lakes	35
Direct-Delayed Response Project	36
Data Management and Analysis for the National Stream Survey	37

Numeric Data Base Established for the Remedial Action Program	37
Comparative Toxicology for Marine Fish and Crustaceans	38
Intruder Scenarios for the Oak Ridge Low-Level Waste Burial Grounds	39
Strategy and Closure Criteria Development for the ORNL Remedial Action Program: Regulatory Interface	40
References	41
4. TERRESTRIAL ECOLOGY	42
Introduction	42
Physiological Ecology	45
Stress Physiology in Terrestrial Vegetation: The Physiological Site of Ethylene Action in Carbon Dioxide Assimilation	45
Symbiotic Activity in Woody Plants Stimulated by Atmospheric Carbon Dioxide Enrichment	45
Biogeochemical Cycling	47
Preliminary Evaluation of Chernobyl-Derived Radioactivity Measured in Oak Ridge May 7 to June 3, 1986	47
Subsurface Transport Project	49
Radiosulfur Cycling Research at Walker Branch Watershed	50
Integrated Forest Study	51
Ecosystem Dynamics	52
National Environmental Research Park	52
Climatic Change in the Amazon Region	53
Multiple Nutrient Limitations in Ecological Processes	54
 PART II. ENVIRONMENTAL SCIENCES DIVISION PROGRAMS	
5. BIOMASS PRODUCTION	55
Introduction	55
Growth Modeling of Wood Energy Crops	56
The Tree-Level Ecophysiological Model	56
The Stand-Level Ecophysiological Model	56
Integration of Tree- and Stand-Level Models	59
Improvement of Herbaceous Lignocellulosic Energy Crops	59
Improvement of Oilseed Energy Crops	62
References	63

6. CARBON DIOXIDE RESEARCH PROGRAM	64
Introduction	64
Extramural Research	65
Development of a Three-Dimensional Model of the Natural Carbon Cycle in the Oceans and Its Perturbation by Anthropogenic CO ₂	65
The Effect of Pressure on Aragonite Dissolution Rates in Seawater	66
Assessment of Seasonal and Geographic Variability in CO ₂ Sinks and Sources in the Ocean	67
The Role of Tropical Forests in the Global Carbon Cycle	68
Comparison of Pre- and Post-Atomic-Bomb Radiocarbon in Soils	68
The Role of CaCO ₃ Compensation in the Glacial-to-Interglacial Change in Atmospheric CO ₂ Content	69
The Role of Ocean CO ₂ Sources and Sinks in the Southern Hemisphere: Data Analysis and Modeling	69
Increase of Total CO ₂ in the World Oceans	70
Study of CO ₂ Source and Sink Distributions with a Three-Dimensional Model	71
Intramural Research	71
Sensitivity and Uncertainty Analysis of a Model of Forest Development	71
Modeling the Seasonality of Terrestrial Contributions to Atmospheric CO ₂	72
CO ₂ Enrichment and Mineral Nutrition of White Oaks	72
Changing Carbon Storage and Carbon:Nitrogen Ratios in Cultivated Soil	73
Seasonal Variability of pCO ₂ in the Northern Atlantic Surface Water	74
References	75
7. CARBON DIOXIDE INFORMATION CENTER	76
Introduction	76
Data and Information Analyses	77
Numeric Data and Computer Model Packages	77
Global Climate—Resource Studies	77
Music Analysis	79
Climatic Indices	81
Information Distribution	81
Request and Response Records Systems	81
Bibliographic Information System	82
Communications	82
Networking	82
Special Projects	83
People's Republic of China	83
Resource Analysis Plan	83
Coordination, Control, and Communication	83
Sea Level Rise	84
References	84

PART III. EXTRAMURAL ACTIVITIES

8. EDUCATION	85
Seminar Program	85
Undergraduate Education Program	88
Graduate Education Program	88
Faculty Program	89
High School Science Teachers Program	92
9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS	93
10. CONFERENCES ORGANIZED OR CHAIRED	106
11. SCIENTIFIC GUESTS	107
12. VISITORS (TOURS AND REGISTERED GUESTS)	110
13. TECHNOLOGY TRANSFER	112

PART IV. APPENDICES

PUBLICATIONS, PRESENTATIONS, THESES, AND PROFESSIONAL ACTIVITIES...	114
Publications	114
Presentations	132
Theses	147
Professional Activities	147
ORGANIZATION CHART	185

ENVIRONMENTAL SCIENCES DIVISION AWARDS AND HONORS

C. C. COUTANT

Martin Marietta Energy Systems, Inc., Publication Award, 1986.

D. L. DeANGELIS

Martin Marietta Energy Systems, Inc., Publication Award, 1986.

J. W. ELWOOD

Fellow, American Association for the Advancement of Science.

M. P. FARRELL

Martin Marietta Energy Systems, Inc., Operational Performance Award, 1986.

Miami University, Institute of Environmental Sciences, Award of Distinction, 1986.

R. H. GARDNER

Environmental Sciences Division Scientific Achievement Award, 1985.

C. W. GEHRS

Fellow, American Association for the Advancement of Science.

D. W. JOHNSON

Martin Marietta Energy Systems, Inc., Technical Achievement Award, 1986.

S. E. LINDBERG

Martin Marietta Energy Systems, Inc., Technical Achievement Award, 1986.

J. F. McBRAYER

American Society for Surface Mining and Reclamation, Appreciation Award, 1986.

S. B. McLAUGHLIN

Martin Marietta Energy Systems, Inc., Publication Award, 1986.

W. M. POST

Martin Marietta Energy Systems, Inc., Publication Award, 1986.

S. F. RAILSBACK

Professional Engineer's License, Civil Engineering, State of California, 1986.

V. R. TOLBERT

American Society for Surface Mining and Reclamation, Appreciation Award, 1986.

J. R. TRABALKA

U.S. Department of Energy Headquarters Commendation, 1986.

PART I. ENVIRONMENTAL SCIENCES DIVISION SECTIONS

1. AQUATIC ECOLOGY

C. W. Gehrs

L. M. Adams ¹	V. M. Davidson	R. A. Jernigan ¹	L. E. Roberson
S. M. Adams	D. L. DeAngelis	B. D. Jimenez ¹	D. Rosenberg ⁶
E. Anderson ²	C. H. Dixon ²	A. R. Johnson ¹	M. G. Ryon ⁸
E. Amaral ³	E. L. Domingue ⁹	C. A. Kauker ⁶	K. R. Seeley ¹
B. H. Armour	J. L. Elmore ¹⁰	B. L. Kimmel	K. L. Shepard ¹
R. D. Bailey	J. W. Elwood	A. W. King ¹	L. R. Shugart ¹⁹
S. M. Bartell	M. Evans ¹¹	W. C. Kyker	G. A. Smith ¹⁵
D. L. Benson ¹	L. S. Ewald ¹⁰	V. O. Levine	J. G. Smith ⁸
M. S. Bevelheimer ¹	G. H. Ezell ¹²	J. M. Loar	S. E. Smith ⁶
M. C. Black ¹	L. A. Ferren ¹³	J. F. McCarthy	D. M. Soballe ¹⁸
B. G. Blaylock	C. J. Ford ¹¹	S. D. Meads ¹⁴	J. A. Solomon
H. L. Boston	P. J. Franco	P. L. Metler ¹	G. R. Southworth
A. L. Brenkert ⁴	M. L. Frank	A. T. Mikell ¹⁵	A. J. Stewart
J. A. Burris ⁵	R. H. Gardner	R. A. Minear ¹⁶	L. M. Stubbs
L. Burrus ⁶	D. M. Genung ¹³	D. Mohrbacher ¹	C. E. Textor ¹²
L. Burtis ⁶	C. T. Hadden ¹⁰	J. S. Montana ¹⁷	R. L. Tyndall ¹⁸
W. D. Burton ⁷	N. S. Hardin	G. P. Morris ¹⁰	W. Van Winkle
G. Cacheiro ¹	G. J. Haynes	P. J. Mulholland	D. C. White ¹⁵
S. W. Christensen	F. O. Hoffman	A. V. Palumbo ¹⁸	D. K. Whitmore
Z. Combs ⁸	M. A. Huston	T. N. Phelps ¹⁵	L. F. Wicker
R. B. Cook	K. Ironsides ¹	S. L. Pimm ¹	C. T. Woodard
D. K. Cox	D. Jacobson ⁶	J. Richmond ¹⁰	L. A. Woodward ¹

¹University of Tennessee, Knoxville.

²Summer Teacher Exchange Program.

³Instituto de Radioprotecao e Dosimetria, Rio de Janeiro, Brazil.

⁴Science Applications International Corporation, Oak Ridge, Tennessee.

⁵Graduate student, University of North Carolina, Chapel Hill.

⁶Summer Research Intern, Oak Ridge Associated Universities, Oak Ridge, Tennessee.

⁷Graduate Professional Opportunities Program.

⁸Information Resources Organization, ORNL.

⁹East Tennessee State University, Kingsport.

¹⁰Oak Ridge Research Institute, Oak Ridge, Tennessee.

¹¹Graduate Program in Ecology, University of Tennessee, Knoxville.

¹²Professor, Chemistry Department, Millsaps College, Jackson, Mississippi.

¹³Part-time.

¹⁴Southern College and University Union.

¹⁵ORNL/UT Distinguished Scientist Program.

¹⁶Professor, Institute for Environmental Studies, University of Illinois, Urbana.

¹⁷Great Lakes College Association/Associated Colleges of the Midwest.

¹⁸Research Associate, University of Tennessee, Knoxville.

¹⁹Biology Division, ORNL.

Introduction

Research in the Aquatic Ecology Section is directed at understanding the way aquatic ecosystems operate and at predicting how aquatic resources will respond to the stresses of anthropogenic activities. Four research groups are currently active: Biogeochemical Cycling, Biomonitoring, Ecosystem Dynamics, and Toxicology and Ecological Effects.

Aquatic research emphasizing biogeochemical cycling focuses on the transport and transformation of radionuclides, nutrients, and energy-related contaminants. The two summaries of radionuclide research presented below highlight the use of ^{131}I fallout from the Chernobyl accident to test the predictions made by mathematical models of the transfer of radioiodine from air to vegetation to milk and the use of radionuclides as tracers to quantify the relationship between contaminant input, deposition, and accumulation in a reservoir embayment. The summary of our biogeochemical research in streams highlights the chemical and biological characteristics of acidic and circumneutral streams in the Southeast and the Adirondacks of New York.

A biological monitoring program is required as a condition of the National Pollutant Discharge Elimination System (NPDES) permits issued recently to each of the three U.S. Department of Energy (DOE) facilities on the Oak Ridge Reservation [Y-12 Plant, Oak Ridge National Laboratory (ORNL), and Oak Ridge Gaseous Diffusion Plant]. These programs are being developed and implemented by a diversity of staff in the Environmental Sciences Division. Our approach to biomonitoring involves the application of fundamental ecological principles (1) to assess the effects of effluent discharges on the biotic integrity of area streams, (2) to evaluate various remedial action alternatives, and (3) to determine the resiliency of ecosystems following such actions.

Aquatic research directed toward understanding the dynamics of whole ecosystems and the functioning of ecosystem components continues to be a major focus in the Section. Three lines of research were pursued in the Ecosystem Dynamics Group during FY 1986: (1) theoretical and experimental studies of nutrient cycling and ecosystem resilience, (2) laboratory studies designed to increase the lipid yield of microalgae, and (3) field studies in which a naturally occurring radionuclide (^7Be) is being used as a tracer for investigating the transport and fate of contaminants in freshwater ecosystems.

The Toxicology and Ecological Effects Group conducts research directed toward understanding and quantifying the fate and effects of potentially toxic chemicals in the aquatic environment. The role of physicochemical partitioning in the transport and biological availability of organic contaminants is examined through a combination of laboratory and field studies. The Lake Acidification and Fisheries Project focuses on developing and applying models that use laboratory bioassay data to predict the response of fish populations in the field to acidification. Efforts during the past year have involved further analyses of the bioassay data on brook trout from the University of Wyoming, organizing and hosting a workshop titled "Predicting Responses of Fish Populations to Acidification," and applying a framework for using both laboratory and field information to predict regional acidification effects on brook trout populations in the Adirondack region of New York State. Ecosystem models forecasting the likely effects of toxic chemicals on the production dynamics of aquatic systems continue to be evaluated and refined. Sensitivity and error analyses of a limnetic water column model quantified the relative contribution of different model parameters to the production dynamics of populations of aquatic plants and animals in the model. Identification of the relative sensitivity of forecasted effects to uncertainties in the values of model parameters will help focus resources to obtain more accurate model forecasts.

A major activity of the Toxicology and Ecological Effects Group has been an effort to assess the toxicity of industrial effluents and their effects on the DOE sites in Oak Ridge. Two components of the effort are highlighted in this report. Aquatic bioassays are being used both to assess the toxicity of effluents from specific industrial processes and to routinely monitor the water quality of streams into which the effluents are discharged. An example of this work is described below. More subtle and long-term effects of contaminant input on aquatic biota are being evaluated by measuring a variety of biological markers that either quantify exposure to contaminants or provide an indication of adverse effects on the animals. During the last year, a variety of indicators were developed, screened, and applied to fish from polluted and pristine streams. The preliminary results indicate a gradient of decreasing levels of adverse chronic effects in fish sampled at increasing distances from the source of pollution. Laboratory experiments are being initiated to demonstrate causal relationships between contaminant exposure and changes in a suite of biological markers.

The Use of Chernobyl Fallout to Test Model Predictions of the Transfer of Radioiodine from Air to Vegetation to Milk

B. G. Blaylock, M. L. Frank, F. O. Hoffman, C. R. Olsen,¹ Z. Combs, E. Amaral

The Chernobyl accident resulted in numerous measurements of concentrations of ^{131}I in air, vegetation, and milk from a variety of locations in different countries. These data provide an opportunity to test predictions made with mathematical models of the air-vegetation-milk transfer of ^{131}I . Data on the concentrations of ^{131}I in air, vegetation, and milk from reports received from Italy, France, Belgium, and the Federal Republic of Germany, and from samples collected in the vicinity of Oak Ridge National Laboratory have been analyzed. These data represent a total of 11 different locations and constitute what is very likely the largest data base ever assembled for testing model predictions of the air-pasture-cow-milk transfer of ^{131}I .

A comparison of observed values with model predictions indicates a tendency for the models to overpredict the air-vegetation-milk transfer of Chernobyl ^{131}I by a large margin (1 to 2 orders of magnitude). The extent of these overpredictions is much larger than indicated by previous attempts at model validation for the ^{131}I air-grass-cow-milk pathway. At only one location, Grenoble, France, did the model predictions come within a factor of 2 of the observed data. Detailed analysis of the data indicated that, in general, most overpredictions were accounted for by the portion of the air-pasture-cow-milk pathway dealing with the transfer from air to pasture vegetation rather than the transfer from vegetation to milk. For the transfer from vegetation to cow's milk, model predictions were generally within a factor of 2, except for data collected from the states of Baden, Bavaria, and Westphalia in the Federal Republic of Germany and from Ispra, Italy. At these locations, overpredictions of the vegetation-to-milk transfer ranged from a factor of 4 to almost 1 order of magnitude.

A precise determination of the cause of the model overprediction requires the acquisition of detailed information on site-specific conditions prevailing at the time the measurements were made. A partial analysis, using available data to infer site-specific conditions and parameter values, indicates that differences between the model predictions and the observations can be explained by (1) overestimation of the fraction of the total amount of ^{131}I in air that was present as molecular

¹Earth Sciences Section, ESD.

vapor, (2) overestimation of wet and dry deposition of elemental and organic iodine and particulate aerosols, (3) overestimation of initial interception by vegetation of material deposited during severe thunderstorms, (4) underestimation of the rates of dilution, by means of weathering and growth, of material deposited on vegetation during periods of spring growth, (5) underestimation of the amount of uncontaminated feed consumed by dairy cows, and (6) overestimation of the diet-to-milk transfer coefficient for ^{131}I . Many of the parameter values assumed in the models are representative of average conditions and do not vary as a function of the time of the year. Therefore, some of the factors identified above imply that the model overpredictions may have been less if the accident had occurred in summer rather than in spring. Correcting the model predictions to accurately simulate the data would result in calculated human exposures from the consumption of contaminated milk by average adults of the same order of magnitude as exposure from direct inhalation of ^{131}I in air.

**The Use of Chernobyl Fallout to Quantify the Transfer
of Submicron Aerosols from Rain to Vegetation and to
Test Natural ^7Be as an Environmental Tracer**

F. O. Hoffman, I. L. Larsen,¹ M. L. Frank, B. G. Blaylock,
C. R. Olsen,¹ and Z. Combs

The Chernobyl accident provided an opportunity to investigate the use of fallout radionuclides as tracers of the rain-to-vegetation transfer of submicron aerosols and to evaluate the potential for naturally occurring ^7Be to quantify the rain-to-vegetation transfer of various submicron aerosol constituents in the atmosphere. From early May through mid-June data were collected on the total atmospheric deposition and concentration of ^{131}I , ^{103}Ru , ^{134}Cs , and ^{137}Cs from the Chernobyl accident, and of natural ^7Be in bulk rain samplers and on indigenous species of pasture vegetation in the vicinity of ORNL. The radionuclides were measured using gamma spectrometry with a germanium-lithium detector.

Analysis of the data indicates that the efficiency of the radionuclide transfer to, and retention by, vegetation (calculated from the amount deposited by rain per unit ground area) decreased with increasing precipitation. These results reflect the process of saturation of vegetation surfaces with increasing precipitation, leading to enhanced wash-off, which decreases the efficiency with which constituents in rain are adsorbed and increases the efficiency of removal of previously deposited material. Analyses based on radionuclide concentrations in rain indicate that, as daily precipitation increased between zero and 10 mm, radionuclides accumulated on vegetation. However, when rainfall exceeded 10 mm per day, a steady-state relationship between rain and vegetation was approached, with average concentration ratios varying between 30 and 70 [pCi/kg vegetation (dry wt):pCi/L rain]. This observation indicates that during high-intensity rainfall the rate of radionuclide removal from vegetation surfaces approximates the rate of accumulation. Above 20 mm of daily precipitation, the average concentration ratios decreased only slightly, suggesting that the removal from vegetation surfaces of previously deposited radionuclides by the more dilute rain that falls toward the middle and end of a storm event is only moderately enhanced with increased precipitation.

¹Earth Sciences Section, ESD.

Beryllium-7 appears to be a suitable tracer for the major processes affecting aerosol deposition and the interception and retention by vegetation of constituents in rain. A strong correlation was found between the rain-to-vegetation transfer of ^7Be and that of the Chernobyl radionuclides (Fig. 1.1). An additional comparison was made using preliminary data obtained from the Environmental

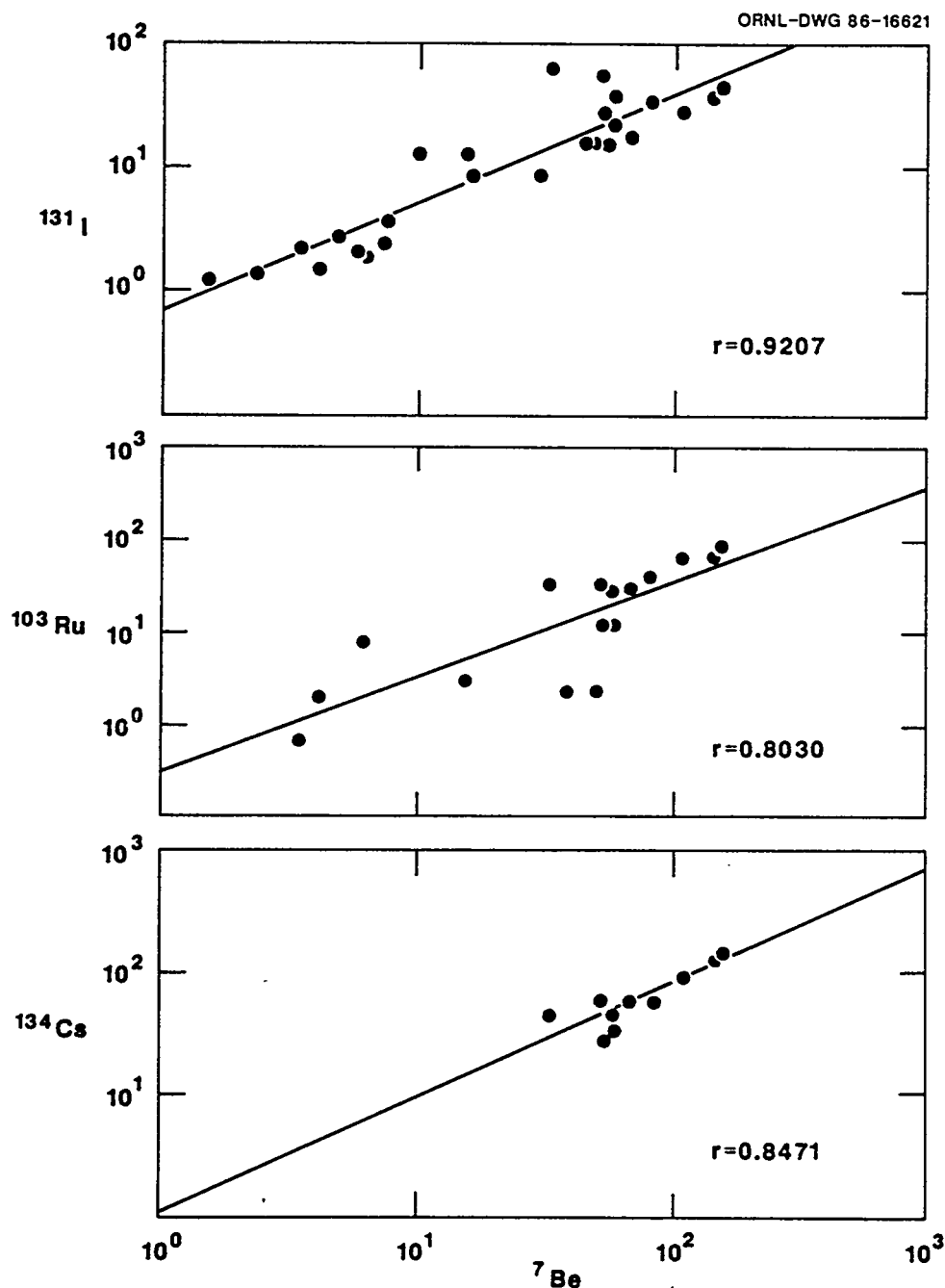


Fig. 1.1. Rain-to-vegetation transfer factors for Chernobyl radionuclides plotted against those for naturally occurring ^7Be . The transfer factors are expressed as concentration ratios [pCi/kg vegetation (dry wt):pCi/L rain]. (r = correlation coefficient.)

Measurements Laboratory (EML) monitoring site near Chester, New Jersey (M. Dreicer, Environmental Measurements Laboratory, New York, personal communication to F. O. Hoffman, August 13, 1986). The EML data showed that ^7Be was nearly a direct tracer of the rain-to-vegetation transfer for Chernobyl fallout. However, the relationships between ^7Be and Chernobyl fallout developed at ORNL (Fig. 1.1) produce lower values than those obtained with the EML data. These differences are nevertheless within the uncertainty associated with radiometric analysis and the differences in methods of sample collection and preparation.

We hypothesize that the physical processes controlling the interception and retention of ^7Be by vegetation are similar to those affecting the Chernobyl radionuclides, and that such processes dominate over obvious differences in chemical adsorption and desorption. Therefore, naturally occurring ^7Be should be useful as a quantitative tracer of the rain-to-vegetation transfer of other submicron aerosols in the atmosphere.

Radionuclides as Tracers to Quantify the Relationship Between Contaminant Input, Deposition, and Accumulation in Aquatic Environments

C. R. Olsen¹ and I. L. Larsen¹

We have measured the particle-to-water distribution of atmospherically derived radionuclides in aquatic systems to quantify the rates of sorption onto suspended matter and the rates of removal from the water column by settling particles. In addition, we have measured the vertical distribution of these radionuclides in sediment cores to document the rates and patterns of particle deposition.

The particle-to-water distribution coefficients (R_s 's) measured in large-volume water samples collected in the Walker Branch embayment of Melton Hill Reservoir range from $\sim 10^3$ for Chernobyl-derived ^{131}I and ^{140}La to 10^5 for ^{103}Ru , ^{134}Cs , ^{137}Cs , and naturally occurring ^7Be and ^{210}Pb . The sorption rates for particle-reactive radionuclides (i.e., $R_s \geq 10^5$) were dependent on the concentration of suspended matter and range from 10 to 20% per day. Residence times for these radionuclides in the embayment waters range from 5 to 10 d.

The vertical distributions and inventories of radionuclides in sediment cores indicate that radionuclide accumulation is spatially heterogeneous. Radionuclide inventories in embayment sediments range from 50 to 100% of the inventory expected from their atmospheric flux. These data indicate that the embayment serves as an effective (short-term) trap for fine particles and particle-reactive contaminants. In future work we will continue to use radionuclides as tracers to quantify the relationship between contaminant input, deposition, and accumulation in aquatic environments.

Ecological Effects of Acidification on Low-Order Woodland Streams

J. W. Elwood, M. A. Bogle,¹ H. L. Boston, R. B. Cook, L. A. Ferren,
D. M. Genung, P. J. Mulholland, A. V. Palumbo, and R. R. Turner¹

Work continued in the third year of this 3-year project on the chemical and biological effects of acidification on woodland streams in the southern Appalachian Mountains of Tennessee and North Carolina and in the Adirondack Mountains of New York. The project is funded by the Electric Power Research Institute. Studies focused on defining the chemical and biological characteristics of selected acidic and circumneutral streams in these two regions.

¹Earth Sciences Section, ESD.

Some potential indirect effects of surface water acidification are (1) a reduction in available phosphorus in surface waters due to reduced mineralization of organic phosphorus under acidic conditions (low pH, high aluminum concentration), (2) increased sorption of phosphate to soils and sediments under acidic conditions, and (3) adsorption and/or coprecipitation of phosphorus by aluminum hydroxide, which is precipitated from acidic solutions as pH increases downstream. To examine the effect of acidification on soluble phosphorus concentrations in stream water, we conducted studies of phosphorus and aluminum dynamics at sites covering a range of pH and aluminum levels. The results indicate that both monomeric aluminum and soluble phosphorus are removed from stream water when pH increases from 4.5 to >5.0. Soluble phosphorus levels were minimal at sites with a pH of 5.0 to 6.0, which were downstream from more acidic reaches.

Tracer studies in which $^{33}\text{PO}_4$ was added to stream water from acidic sites, followed by NaOH additions to increase the pH (from 4.5 to >5.5), showed rapid loss of $^{33}\text{PO}_4$ from solution through adsorption of phosphate on small particles and/or coprecipitation of phosphate with small particles (0.1 to 0.2 μm). Assays of phosphatase, an exoenzyme associated with the epilithic community on rocks, indicated that this community was more phosphorus limited at, and downstream from, reaches where aluminum and phosphorus were removed from solution. Together, these results indicate that surface water acidification can increase phosphorus limitation and consequently reduce productivity of aquatic systems downstream. This increase in phosphorus limitation occurs downstream from the most acidic reaches of the drainage and appears to be caused by the adsorption and/or coprecipitation of aluminum and phosphorus as pH increases.

There are other indirect and direct effects of acidification on bacterial and periphyton communities in the study streams, although the two communities exhibit contrasting responses. Epilithic bacterial production was significantly lower in highly acidic streams (pH <5) compared with streams similar in size, elevation, order, and location but with pH values >6. Bacterial production and microbial respiration on leaf material were also reduced in the highly acidic streams. The decomposition rates of leaves in the streams with pH values <6 were lower than the rates in the higher-pH streams, largely because of the reduced microbial respiration associated with the leaves. Aluminum accumulated on decomposing leaf material at a faster rate in the low-pH streams, suggesting that aluminum toxicity may be a cause of the lower microbial respiration observed.

In contrast to the response of bacteria to acidic conditions, periphyton biomass and production (per unit surface area) were greater in the highly acidic streams. There were also large changes in periphyton community composition with acidification. Streams with pH values >5.5 were dominated by small blue-green algae and chrysophytes, whereas streams with pH values <5.0 were dominated by diatoms and green algae.

The acidification of streams (and its effects on bacteria and periphyton observed in our studies) is very likely due to both the chemistry of the stream water (direct effect) and changes in the macroinvertebrate community (indirect effect). Experimental manipulations of pH and aluminum indicated that low pH (<5) and/or high concentrations of inorganic monomeric aluminum (>0.2 mg/L) reduced the production of bacterial and periphyton communities from a stream with an ambient pH of >6. Experimental manipulations of macroinvertebrate grazer densities indicated that bacterial production was reduced and periphyton biomass and production were increased at low grazer densities. We conclude from these studies that reduced pH, increased aluminum concentrations, and reduced density of macroinvertebrate grazers may all contribute to reduced bacterial production in highly acidic streams. Although reduced pH and increased aluminum concentrations may account for the shifts observed in the species composition of the periphyton community, the

increased periphyton biomass and production in the highly acidic streams are primarily the result of a reduction in the number of macroinvertebrate grazers.

Preliminary Screening of Radionuclides in White Oak Lake and Environs for Remedial Action Scenarios

B. G. Blaylock, M. L. Frank, F. O. Hoffman, and D. Mohrbacher

A screening analysis for radionuclides in White Oak Lake and its environs is being conducted to identify radionuclides and critical pathways that pose potential problems for human exposure. The analysis addresses three remedial action scenarios: (1) the lake is maintained in its current state, and the public is allowed free access to the lake and its environs; (2) the lake is completely drained, and the public is allowed free access to the area; and (3) the lake is drained, sediments are either excavated or capped, a canal is constructed around the area to divert the flow of White Oak Creek into the Clinch River, and the public is allowed free access.

The exposure pathways considered include terrestrial and aquatic food-chain pathways as well as external exposure to sediment, soil, and water from a variety of outdoor activities (e.g., swimming, sunbathing, etc.). The most recent data on concentrations of radionuclides in the soils, sediments, water, and biota of White Oak Lake and environs were used in the screening analysis. When environmental data were not available, appropriate mathematical models were used to predict the concentrations of radionuclides for the environmental parameters needed in the screening analysis. The primary radionuclides considered for screening in the food-chain pathways were ^{137}Cs , ^{60}Co , and ^{90}Sr . In addition, tritium was evaluated for external exposure pathways.

For the hypothetical terrestrial food chain, the greatest dose contributions would be expected from ^{137}Cs in beef and milk from cows grazing on the White Oak Lake floodplain. Vegetables grown on the lake bed and consumed by humans would also be a ^{137}Cs pathway of concern. The dose contributions from the aquatic food-chain pathway were more than a factor of 10 less than the contributions from the hypothetical terrestrial food-chain pathway. Cesium-137 and ^{90}Sr in fish and ^{137}Cs and ^{60}Co in aquatic plants were the major dose contributors from the aquatic food chain. Additional screening of all radionuclides, including the transuranic elements, will be completed in the near future, and dose calculations for the various pathways will be compared with appropriate standards. In addition to identifying critical food-chain pathways and problem radionuclides, this analysis will help identify the research efforts needed for remedial actions on White Oak Lake.

Bioaccumulation Monitoring in the Y-12 Biological Monitoring and Abatement Program

G. R. Southworth

The Y-12 Plant must conduct a biological monitoring and abatement program (BMAP) in East Fork Poplar Creek as a condition of its NPDES discharge permit issued by the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Health and Environment (TDHE). The objective of the monitoring program is to ensure that East Fork Poplar Creek downstream from all Y-12 Plant discharges meets the criteria for various uses, as designated by the TDHE. Of greatest significance is the use of the stream for the growth and propagation of fish and

aquatic life. One criterion for meeting this classification is that discharges do not result in the accumulation of hazardous levels of toxic substances in aquatic organisms in the receiving water. A component of the BMAP therefore addresses the problem of bioaccumulation.

East Fork Poplar Creek downstream from Y-12 is currently closed to fishing and swimming because of the excessive levels of mercury in fish and sediments found there. Studies conducted in 1984 suggested that polychlorinated biphenyl (PCB) and polycyclic aromatic hydrocarbon (PAH) contamination may also be a problem in the stream. A primary objective of the bioaccumulation task of the BMAP is to closely monitor changes in the levels of mercury and PCBs in fish throughout the length of East Fork Poplar Creek as efforts continue within the Y-12 Plant to isolate and abate sources of these contaminants. Clams were maintained in cages in the discharge from New Hope Pond to monitor PAHs, which do not accumulate in fish due to their rapid conversion to more polar metabolites.

The results of the 1985-1986 monitoring of mercury in redbreast sunfish (*Lepomis auritus*), bluegill sunfish (*Lepomis macrochirus*), and carp (*Cyprinus carpio*) indicate that mercury levels in fish from East Fork Poplar Creek have decreased substantially since 1982-1984, but that the levels in many fish still exceed the action level of 1 ppm (by weight) set by the Food and Drug Administration (FDA). Mercury levels in the fish appear to have remained stable over the past year. The highest levels are found at the sampling site immediately below New Hope Pond, and they decrease steadily with distance downstream. A pattern very similar to that of mercury was observed for PCBs, with the highest levels found immediately below New Hope Pond and a steady decrease with distance downstream. While the levels of PCBs in sunfish are well below the FDA limit of 2 ppm (by weight), the levels in many carp collected in East Fork Poplar Creek in 1985-1986 exceeded this standard. The levels of PAHs observed in clams were low and did not differ from those found in clams from the reference sites, despite the known presence of elevated levels of PAHs in the sediments of East Fork Poplar Creek and New Hope Pond. It appears likely that the PAHs in those sediments are associated with coal particles and are not biologically available.

Efforts to reduce the discharge of mercury and PCBs appear to have resulted in noticeable improvements over a relatively short period of time. Continuing efforts in this area and research into the sources of the continuing contamination of East Fork Poplar Creek biota are needed to restore the stream to an acceptable condition.

Nutrient Cycling, Ecosystem Structure, and Ecosystem Stability

D. L. DeAngelis, B. L. Kimmel, J. W. Elwood, P. J. Mulholland,
W. M. Post,¹ S. M. Bartell, D. M. Soballe, and A. V. Palumbo

Most theoretical models of ecological food webs have considered only the biomass or energy dynamics of the interacting populations. It is increasingly being recognized, however, that because nutrients are often limiting factors in ecosystems, nutrient cycling must be included in food web models. We believe that the full importance of nutrient limitations in shaping ecosystem dynamics, structure, and stability has not been realized. We believe that this is a result of a failure to effectively link existing theory with empirical results and a lack of direct, systematic investigation.

¹Terrestrial Ecology Section, ESD.

Furthermore, we believe that, to advance our understanding of ecosystem stability, an experimental evaluation of the relationship between the nutrient cycling properties and the stability of ecological systems is now required.

The central thesis of our research is the following. Ecosystem stability results from the system's capacity to compensate for environmental fluctuations. This capacity is a product of the interrelationships of the species and functional components of the system. These interrelationships are, in turn, constrained by the supply of essential nutrients and by the disturbance regime. Figure 1.2 illustrates this postulated chain of influence from environmental nutrient constraints through ecosystem structure and function to stability.

ORNL-DWG 85-10940

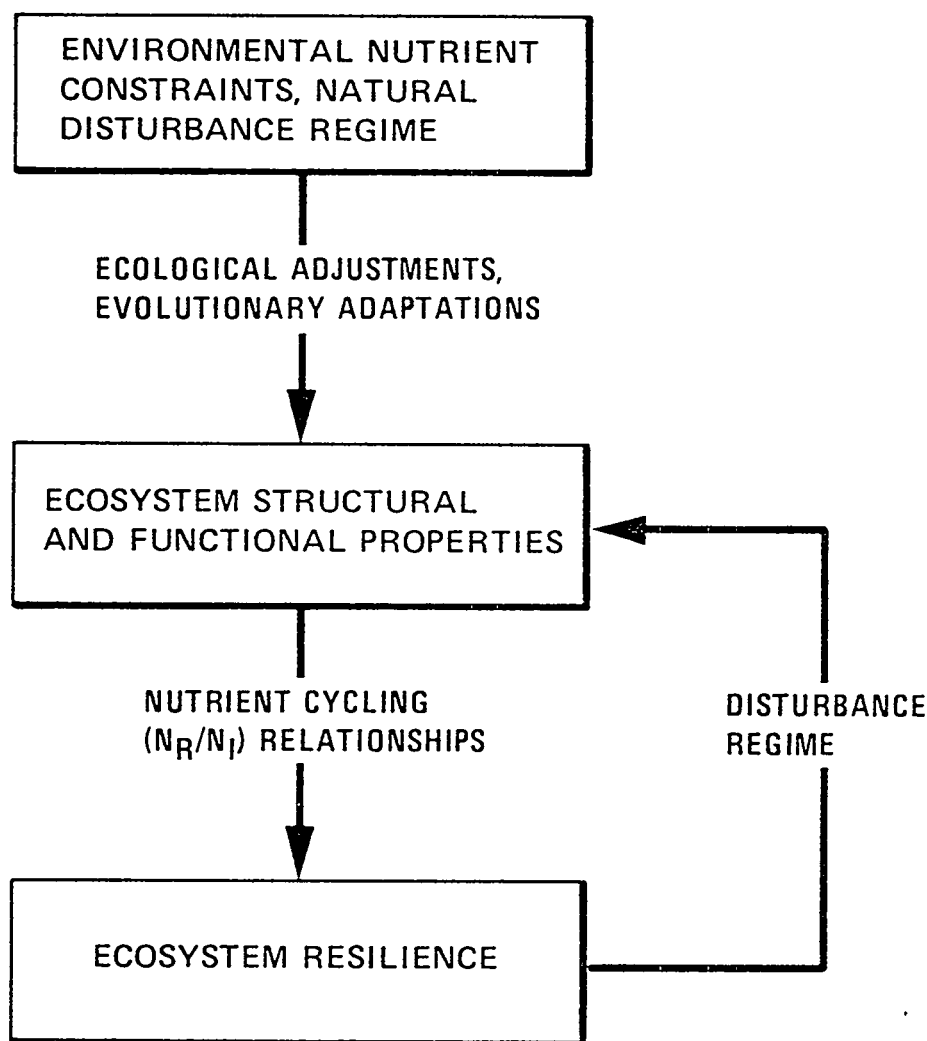


Fig. 1.2. Hypothesized interrelationships of environmental nutrient constraints, ecosystem structure, ecosystem resilience, and disturbance regimes. (N_R = recycled nutrients, N_I = nutrient input.)

Under a grant from the National Science Foundation Ecosystem Studies Program, we have begun a project this year to test predictions regarding the interrelationships of nutrient cycling and ecosystem resilience. This cannot be done easily in natural systems, but a set of recirculating artificial streams in which nutrient input and recycling can be controlled is available in the Environmental Sciences Division. Simple food webs will be established in these artificial streams, and their responses to perturbations will be quantified in relation to food web structure and nutrient recycling characteristics.

In work performed so far on this project, we have shown by theoretical analysis and computer simulations that, in food webs with autotrophs controlled from the bottom up, ecosystem resilience is relatively insensitive to the nutrient input rate, whereas in ecosystems controlled from the top down, the resilience generally increases with increasing nutrient input. However, the latter result depends strongly on the details of the nutrient recycling under conditions of top-down constraints. If nutrients from harvested biomass are returned quickly to the system, resilience can be higher than if they are not. These theoretical results will be tested experimentally in the artificial streams.

Our research is an attempt to link theory with empirical results and has implications for both aquatic and terrestrial ecosystems. Our experimental results, in combination with dynamic ecosystem simulation models, will form the basis for new system-level theory on the relationship between the nutrient cycling properties and the stability of ecological systems.

Increasing Microalgal Lipid Yields Through Flow Cytometry

J. A. Solomon and R. E. Hand, Jr.¹

Many microalgae synthesize and store oils which may be usable, with few conversion steps, as a replacement for liquid fuels. The Solar Energy Research Institute is developing a technology to optimize microalgal oil production, relying on low-value resources such as saline water in arid regions, and currently has 20 promising microalgal strains in culture. Our research focuses on increasing the average lipid content of these algae.

A range of lipid content is found in the cells of any algal population. It may be possible to increase the lipid yield of an algal culture by separating and growing only those cells with the highest lipid content. The relatively new technique of flow cytometry provides a means of making measurements on each individual cell of a population. Based on these measurements, cells with a particular combination of traits can be selected and physically separated (sorted) from the remainder of the population. In this study, nitrogen-deficient algal populations were analyzed for chlorophyll and lipid content simultaneously. Two subpopulations, one of high lipid content and one of low lipid content, were separated from the remainder of the population. The sorted cells were grown and later reanalyzed for lipid content.

In two of eight cases, the lipid content of the high-lipid fraction was 2.5 to 3.5 times greater than that of the low-lipid fraction. Development of higher lipid levels in any population followed a reduction in the chlorophyll:lipid ratio. Interestingly, the population distribution was bimodal, with cells having one of two chlorophyll:lipid ratios. This suggests that the cells are in one of two metabolic states, either a normal-growth phase or a lipid-accumulation phase, and that the transition

¹Biology Division, ORNL.

between these states is abrupt. The transition appears gradual in batch cultures because of intercellular variation in the timing of the ratio shift.

The fact that high- and low-lipid populations can be produced from a mixed population suggests that lipid content is a heritable trait and is thus amenable to manipulation. Furthermore, the identification of two discrete metabolic states supports the concept of a "lipid trigger," an environmental event which stimulates lipid accumulation. Research is currently in progress to increase the probability of obtaining high-lipid cultures through flow cytometric sorting and to relate the chlorophyll:lipid ratio to the physiological state of the microalgal population.

Beryllium-7 Sorption Kinetics and Water Column Residence Time in River-Reservoir Systems

C. R. Olsen,¹ I. L. Larsen,¹ P. D. Lowry,¹ C. J. Ford, and B. L. Kimmel

We are using the distribution of naturally occurring ⁷Be (53.3-d half-life) to quantify the kinetics of contaminant sorption on suspended matter and the rates of contaminant removal from the water column in freshwater systems. Beryllium-7 enters aquatic systems as a dissolved constituent of rain water. Particle-to-water distribution coefficients measured in the Walker Branch embayment of Melton Hill Reservoir have a median value of $\sim 1.7 \times 10^5$. Large-volume (~ 1000 -L) water and suspended matter samples collected in a time series after major precipitation events indicate that the apparent sorption rates are dependent on suspended matter concentrations. Sorption rates range from 10% per day during the winter to $\sim 20\%$ per day during the spring when biological productivity and runoff increase suspended matter concentrations from ~ 5 to 15 mg/L.

Residence times of ⁷Be in the water column range from 5 to 10 d and correspond well with phytoplankton sinking rates measured in laboratory settling columns. Particle production by phytoplankton appears to play an important role in the removal of ⁷Be from the water column in Walker Branch embayment. Since many chemically reactive substances become associated with fine particles in aquatic systems, the information obtained on the distribution of ⁷Be is applicable for quantifying the types and rates of processes that affect the transport, removal, and biogeochemical fate of other particle-reactive substances.

Interfacing Toxicity Tests with Chemical Analyses to Identify Critical Process Steps in Wastewater Treatment Facilities

A. J. Stewart, L. M. Adams, and L. F. Wicker

Biological tests provide a cost-effective means of determining if contaminants are present at toxic concentrations in chemically complex effluents. It is also possible to use biological tests to identify the agent(s) responsible for the toxicity in complex mixtures, and to identify the operational steps in wastewater treatment procedures that critically affect the toxicity of the final effluent. We recently demonstrated the utility of such biological tests (7-d "minichronic" tests based on the survival and reproduction of the aquatic microcrustacean *Ceriodaphnia* and on the survival and growth of fathead minnow larvae) in assessing problematic operational procedures at the Y-12 Plant's S-3 Ponds Liquid Treatment Facility (S-3 LTF).

¹Earth Sciences Section, ESD.

Effluent discharged from the S-3 LTF was highly toxic to *Ceriodaphnia*, but passed EPA standards with respect to chemical composition. A series of tests showed that the toxicity of the effluent (1) was not reduced by extensive aeration, (2) was not attributable to neutral dissolved salts, (3) disappeared when the substances dissolved in the effluent were brought to dryness before being reconstituted in distilled water, and (4) was virtually eliminated when the effluent was treated with peat moss, which sorbs various heavy metals. The results of the toxicity tests were then compared with results of chemical analyses. In this comparison, the most probable toxicant appeared to be uranium. Depleted uranium was shown to be chronically toxic to fathead minnow larvae at a concentration of 5.2 mg/L, and was acutely toxic to *Ceriodaphnia* at a concentration of ~ 7 mg/L. The uranium concentrations in S-3 LTF effluent were high enough to account for the observed degree of toxicity of the effluent, and the concentrations of uranium in the effluent were lowered markedly by passing the effluent through peat moss.

Experimental S-3 LTF effluents produced at the Y-12 Plant in a series of bench-top alternative wastewater treatment schemes (e.g., the presence or absence of ferric chloride as a flocculating agent; the degree of aeration of the raw feedwater; the pH adjustment of the feedwater during treatment; the presence or absence of polymer) were subsequently tested with *Ceriodaphnia* and analyzed chemically to establish operational procedures to reconcile discrepancies between chemical vs biological acceptability criteria for effluent discharged to receiving streams. The approaches developed in this study show the advantages of using biological and chemical analyses together, and lend credence to the idea that biological tests can serve as powerful diagnostic tools in the analysis of wastewater treatment procedures.

Evaluating Mixed-Function Oxidase and Electron Transport Enzymes in Fish as Indicators of Environmental Pollution

B. D. Jimenez, S. M. Adams, L. Burtis, and S. D. Meads

All organisms possess a number of genetically regulated mechanisms to cope with exposure to toxic contaminants in the environment. One system that responds to a seemingly endless array of chemicals is the detoxication system known as the cytochrome-P-450-dependent mixed-function oxidase (MFO) system. By means of this system, organic xenobiotics are biotransformed to polar compounds that are readily excreted through the kidneys, feces, and gills of fish. We have demonstrated that exposure of fish in the laboratory to xenobiotics results in a dose-dependent induction of the MFO system. We are now exploring the possibility of using MFO induction in feral animals as a biological indicator of exposure to environmental pollution.

Redbreast sunfish (*Lepomis auritus*) were collected from a stream receiving large inputs of industrial effluents and from a control stream in a rural drainage area. The quantities and activities of several hepatic detoxication enzymes and associated electron transport enzymes were found to be significantly higher in animals collected near the industrial outfall. A proper interpretation of the data requires a fundamental understanding of the biology and physiology of the fish in their natural habitat. For example, the titers of reproductive hormones influence the activity of the MFO enzymes: in spring and summer, when estradiol titers are high in female fish, MFO activity was not induced even in females collected near the source of effluents. Seasonal variations in temperature also affect enzyme levels. Electron transport enzymes appear to be useful indicators regardless of

2. EARTH SCIENCES

N. H. Cutshall

N. G. Allred	C. D. Farmer	I. L. Larsen	B. V. Shelton
R. W. Arnseth ¹	N. D. Farrow	S. Y. Lee	C. B. Sherwood ¹
T. L. Ashwood	R. B. Fitts	S. E. Lindberg	R. W. Sobozinski ³
B. L. Baber	C. W. Francis	C. D. Little ⁵	D. K. Solomon
C. M. Beaudoin	B. J. Frederick ¹	P. D. Lowry	B. P. Spalding
W. J. Boegly, Jr.	T. Grizzard	D. S. Marshall	R. G. Stansfield
M. A. Bogle	C. S. Haase	L. A. Melroy ¹	K. F. Steele ⁷
D. M. Borders ¹	R. C. Haese	S. J. Morrison ²	S. H. Stow
P. A. Buntrock	R. D. Hatcher ¹	C. R. Olsen	L. E. Stratton
B. K. Butler ²	M. S. Hendricks	J. G. Owens	J. Switek
T. Cerling ³	S. E. Herbes	T. H. Peng	A. L. Thomas
R. B. Clapp	D. D. Huff	P. H. Pollard	B. J. Tilley ⁸
J. S. Cox	L. K. Hyder	S. B. Redman ²	L. E. Toran
E. C. Davis	A. F. Iglar ⁴	A. I. Scales ¹	V. S. Tripathi
K. C. Dearstone	G. K. Jacobs	D. A. Schaefer ⁶	R. R. Turner
R. B. Dreier	J. R. Jones	O. M. Sealander	K. L. Von Damm
C. H. Fairfax	H. L. King	R. J. Selfridge ⁷	G. T. Yeh

Introduction

The Earth Sciences Section conducts research, development, and demonstration projects in the physical environmental sciences and engineering. Specific projects are carried out in the areas of atmospheric science, surface and groundwater hydrology, geochemistry, geology, geophysics, soil science, and oceanography. The scope of these activities includes field characterization, field and laboratory experimental work, and mathematical and computer modeling. Many of the projects are interdisciplinary in nature and are coordinated with other sections of the Environmental Sciences Division, with other divisions of Oak Ridge National Laboratory, and with collaborators from several universities. The Section consists of four groups: Geology and Geochemistry, Environmental Engineering, Hydrology, and Environmental and Soil Chemistry.

Approximately one-half of the Section's current activities are related to remedial actions at Oak Ridge National Laboratory (ORNL) or the Y-12 Plant and are sponsored by the U.S. Department of Energy (DOE) Office of Defense Waste and Transportation Management and the Office of

¹University of Tennessee, Knoxville.

²Indiana University, Bloomington.

³University of Utah, Salt Lake City.

⁴East Tennessee State University, Johnson City.

⁵Florida State University, Tallahassee.

⁶The Maxima Corporation, Bethesda, Maryland.

⁷University of Arkansas, Fayetteville.

⁸University of Alberta, Canada.

Energy Research. In addition to the specific project activities discussed below, the Section has participated heavily in the design, planning, and management of the ORNL Remedial Action Program. Section staff contribute to the work of the Hazardous Waste Remedial Action Program (HAZWRAP) Management Office at ORNL. Other sponsors of Section projects include the DOE Sedimentary Rock Program, DOE Office of Environment, Safety and Health, the U.S. Nuclear Regulatory Commission (NRC), the U.S. Environmental Protection Agency, the U.S. Navy, the Electric Power Research Institute, and the state of Maryland.

Significant achievements during FY 1986 include the following:

- Organization of a workshop for NRC to resolve issues related to modeling and testing of sorption processes and their relationship to siting of high-level radioactive waste repositories.
- Demonstration of an application of a hypercube parallel-processing computer in geochemical modeling.
- Organization and initiation of site characterization that will enable ORNL Solid Waste Storage Area 6 to continue as the operating disposal site for low-level radioactive wastes.
- Investigation which showed that the Navy's Inactive Fleet operations at Pearl Harbor do not contribute significantly to trace metal contamination of harbor sediments.
- Discovery that dry deposition of nitrate ions is the largest single input of nitrogen to the eastern deciduous forest at Walker Branch Watershed.
- Demonstration of grout fixation of transuranic waste trenches using polyacrylamide.
- Extensive local measurement of fallout radionuclides from the Chernobyl accident in environmental samples.

The Section is providing coordination and leadership for ORNL's participation in the DOE Environmental Survey. This program, which is designed to independently evaluate potential environmental risks at DOE sites, relies on field sampling and chemical analytical support from ORNL. In addition, ORNL is responsible for routing of samples for the survey. Participants besides the Environmental Sciences Division (ESD) are the Environmental and Occupational Safety Division, the Health and Safety Research Division, the ORNL Analytical Chemistry Division, and the Analytical Chemistry Division at the Oak Ridge Gaseous Diffusion Plant.

Dry Deposition of Nitrate to a Forest

S. E. Lindberg, G. M. Lovett,¹ and J. G. Owens

Atmospheric deposition of nitrate is important both in ecosystem nitrogen cycling and as a component of the acidic deposition phenomenon. Wet deposition can be readily quantified, but because dry deposition inputs are difficult to measure, they are often ignored in biogeochemical studies. We developed three separate methods to estimate dry deposition of nitrate to the deciduous forest at Walker Branch Watershed (Lovett and Lindberg 1986): (1) surrogate deposition surfaces (Lindberg and Lovett 1985), (2) a statistical analysis of throughfall (Lovett and Lindberg 1984), and (3) an inferential approach using air concentrations (Lindberg et al. 1986). Estimates of dry deposition

¹Institute of Ecosystem Studies, Cary Arboretum, Millbrook, New York.

flux ranged from 1.8 to 9.1 kg $\text{NO}_3^- \cdot \text{N} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$. With the use of a hybrid approach combining some aspects of all three methods, a best estimate of 4.8 kg $\text{NO}_3^- \cdot \text{N} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$ was derived. About 75% of this flux is attributable to deposition of HNO_3 vapors, with large particles contributing most of the remainder; the contribution from small particles is negligible.

Our best estimate indicates that dry deposition of NO_3^- is the largest single form of inorganic nitrogen deposition to this forest, contributing almost half of the total annual input of 10.1 kg N/ha. All of the enhancement of NO_3^- deposition in stemflow and throughfall relative to incident precipitation can be explained by wash-off of dry-deposited NO_3^- , and some canopy uptake of dry-deposited NO_3^- is suggested. This uptake occurs primarily during the growing season and contributes from 0.2 to 7.5 kg $\text{N} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$ (best estimate: 3.2) to the nitrogen requirements of the ecosystem. Despite the uncertainties, the magnitude of the potential input fluxes to forested ecosystems necessitates consideration of dry deposition of nitrate in ecosystem nitrogen cycling studies.

Collaborative Testing of the Toxicity Characteristic Leaching Procedure

C. W. Francis and M. P. Maskarinec¹

The Environmental Sciences Division and the Analytical Chemistry Division have recently participated in two collaborative testing programs to help the U.S. Environmental Protection Agency (EPA) evaluate the recently proposed Toxicity Characteristic Leaching Procedure (TCLP). The TCLP is a laboratory waste extraction test intended to identify wastes with the potential for releasing specific toxic constituents when they are disposed of in a municipal waste landfill. The TCLP replaces the Extraction Procedure Leaching Test (USEPA 1982) and includes regulatory levels for 38 additional compounds, principally toxic organic compounds. The TCLP was formulated using a data base, developed at ORNL, comparing the leaching of industrial wastes under field disposal conditions and the extraction of the same wastes under laboratory conditions (Francis, Maskarinec, and Goyert 1984; Francis and Maskarinec 1986).

Characterization of and Remedial Action for ORNL Waste Impoundments

C. W. Francis and R. G. Stansfield

Unlined waste impoundments have been used as the traditional method to collect, treat, and dispose of wastewater generated at ORNL. In certain instances, these impoundments represent potential sources of groundwater contamination. For example, sediment in many of the impoundments contains concentrations of radionuclides, toxic metals, and organic compounds that may contaminate groundwater if leached from the sediment. To determine the potential for such contamination, the concentrations of contaminants in the sediment and water in ORNL waste impoundments were characterized. Groundwater-monitoring wells were installed upgradient and downgradient of each impoundment, and the groundwater was analyzed to assess the effects of the impoundments on groundwater quality. Many of the impoundments will require remedial action and closure to be in compliance with state and federal regulations. The remedial action methods best suited to meet the closure criteria are being evaluated.

¹Analytical Chemistry Division, ORNL.

Mercury in Ambient Air at the Y-12 Plant

R. R. Turner, S. E. Lindberg, and M. A. Kane¹

Mercury concentrations in ambient air outside of buildings and on the perimeter of the Y-12 Plant have not been monitored continuously. Sources of mercury in air at Y-12 include (1) buildings, equipment, and soil containing residual deposits of elemental mercury and (2) the coal-fired Y-12 Steam Plant, with an annual emission estimated at 30 kg. Where spot measurements have been made (e.g., near buildings or in areas where the soil is known to be contaminated with mercury), concentrations have nearly always been below detection limits using portable mercury vapor monitors. The detection limits for this type of instrument are typically 1 to 10 $\mu\text{g}/\text{m}^3$, whereas the National Emission Standards for Hazardous Air Pollutants (NESHAP) has established an ambient air standard of 1 $\mu\text{g}/\text{m}^3$. Reliable detection of mercury in air near or below the NESHAP standard has typically required collection and concentration of mercury on an intermediate absorber, such as a noble metal or impregnated activated carbon.

A sampling train consisting of impregnated activated-carbon absorbers (for vapor-phase mercury) and Teflon filters (for particulate mercury) has been developed and deployed at several locations at the Y-12 Plant to obtain ambient air data for mercury. To date, no 3- or 4-d average mercury vapor concentrations have exceeded the NESHAP standard (1 $\mu\text{g}/\text{m}^3$) at any site; the concentrations have ranged from 0.003 to 0.24 $\mu\text{g}/\text{m}^3$, with a 3-month (July–September 1986) average of 0.061 $\mu\text{g}/\text{m}^3$. The local background concentrations of mercury vapor in air appear to be near 0.005 $\mu\text{g}/\text{m}^3$. As additional data become available, the relationship of air concentration to meteorologic and other factors, such as the moisture content of mercury-contaminated surface soils, will be examined.

Nature of pH Variations in Rogers Quarry

R. R. Turner, M. A. Bogle, and B. L. Kimmel²

Rogers Quarry on the Oak Ridge Reservation is used for disposal of coal ash from the Y-12 Steam Plant. Historical records of pH measurements of the effluent from Rogers Quarry show a consistent pattern of excursions above pH 8.5 [the National Pollutant Discharge Elimination System (NPDES) limit value] during warmer months of the year. Water quality measurements throughout the entire water depth at Rogers Quarry in October 1985 and May 1986 showed that pH values >8.5 were restricted to the upper few meters of the water column and that algal biomass (as indicated by chlorophyll *a* measurements) was high in the surface waters. A laboratory study of Y-12 coal ash (from the baghouse) and measurements of the ash sluice water at McCoy Branch showed that ash being sluiced to Rogers Quarry is acidic in character and reduces the acid-neutralizing capacity of surface water entering the quarry, which may increase the sensitivity of quarry surface waters to photosynthesis-driven pH fluctuations.

The results of the study implicate algal growth in Rogers Quarry as the cause of occasional pH excursions above the NPDES limit value of 8.5. Algal blooms in the quarry appear to be related to excessive concentrations of soluble phosphorus. The source of the soluble phosphorus is unknown at

¹Health, Environment, Safety, and Accountability Division, Y-12 Plant.

²Aquatic Ecology Section, ESD.

this time, but it is strongly suspected that it is leached from the coal ash which is sluiced to Rogers Quarry.

Determination of Soil Contaminant Profiles for Y-12 Facilities

S. E. Herbes and R. R. Turner

Plans have been submitted to the Tennessee Department of Health and Environment (TDHE) for closure, under provisions of the Resource Conservation and Recovery Act (RCRA), of several facilities at the Y-12 Plant which have been used in the past for storage or handling of hazardous wastes. To support the closure activities, we prepared soil sampling and contaminant characterization plans for five facilities. Characterization studies at one facility (Salvage Yard Oil/Solvent Drum Storage Area), consisting of augering and sampling of 32 exploratory boreholes, contaminant analysis, and final verification studies, were completed during the period April–September 1986. The levels of hydrocarbons, perchloroethylene, mercury, and lead were elevated above background in surface soils at the site, but the profiles indicated that transport deeper than 2 m did not occur. Analyses indicated that no contaminants, including volatile organics, polychlorinated biphenyls (PCBs), and toxic metals, in soils at the site exceeded the limits specified in the closure plan for initiating remedial action.

To assist in the development of closure plans for the Oil Retention Ponds in the Bear Creek Burial Grounds, we developed a soil sampling program for tributaries draining the area to determine whether oil seepage from burial trenches in the past may have resulted in PCB contamination downstream. More than 100 soil samples were collected and analyzed (by the K-25 Analytical Laboratory) to delineate the patterns of PCB contamination. Elevated PCB concentrations were found in some tributary channel and floodplain sediments both above and below the Oil Retention Ponds, probably due to transport and deposition of PCBs sorbed to fine soil particles in runoff from oil seepage areas. Additional studies are under way to locate past seepage points to support development of remedial action plans.

Immobilization of Buried Transuranic Waste with Acrylamide Grout

B. P. Spalding, S. Y. Lee, C. D. Farmer, and L. K. Hyder

This task is a demonstration and evaluation of in situ hydrologic stabilization of buried transuranic waste at a humid site by means of grout injection. Two small trenches, containing buried transuranic waste, were filled with 34,000 L of polyacrylamide grout. Initial field results have indicated that void space within the trenches was totally filled by the grout and that the intratrench hydraulic conductivity was reduced to below field-measurable values. The grout was also completely contained within the 2 trenches, as no grout constituents were observed in the 12 perimeter groundwater-monitoring wells.

The polyacrylamide grout was selected for field demonstration over a polyacrylate grout because of its superior performance in laboratory degradation studies. Also supporting the selection of polyacrylamide was the difficulty in controlling the set time of the acrylate polymerization process in the presence of potassium ferricyanide. Based on preliminary degradation monitoring, the polyacrylamide was estimated to have a half-life of 115 years in the test soil. However, this calculated value is likely to be conservatively low because microbial degradation of the grout-setting accelerator (triethanolamine) or residual monomer may be contributing most to the measured

microbial respiration. Additional work using ^{14}C -labeled acrylate and acrylamide grouts is being planned next year in an effort to more accurately estimate their microbial degradation rates.

Radionuclides as Tracers in Coastal Zones

C. R. Olsen, I. L. Larsen, P. D. Lowry, W. H. Casey,¹ and L. C. Schaffner²

The particle-to-water concentration ratios of fallout ^{137}Cs , reactor-released ^{137}Cs , ^{134}Cs , ^{65}Zn , ^{60}Co , and ^{58}Co , and natural ^7Be and ^{210}Pb have been measured in the Susquehanna River-Chesapeake Bay system as part of a 3-year study for the Maryland Power Plant Research Program and DOE's Office of Health and Environmental Research (DOE-OHER), and a final report has been completed. The report summarizes our field and laboratory results and discusses implications concerning (1) net transport patterns, (2) rates of sorption and removal from the water column, (3) accumulation rates in sediments and organisms, (4) chemical partitioning between different particulate sorbing phases, and (5) the important biogeochemical processes which affect the fate of radionuclides (and, by analogy, other trace substances or contaminants) in the Susquehanna River-Chesapeake Bay system (Olsen et al. 1986). This work had led to a project to measure the particle-to-water concentration ratios of several natural and anthropogenic radionuclides in the Savannah River Estuary and adjacent coastal zone. The preliminary results indicate that nuclide concentrations associated with releases from the Savannah River Plant and with fallout from the Chernobyl accident in the Soviet Union are detectable within this estuarine-coastal system.

We have conducted field experiments in a coastal wetland to quantify the effects of seasonal cycles in freshwater input, evaporation, and plant transpiration on the movement of radionuclides and trace substances in salt marsh sediments. Foliage preferentially traps wet and dry deposition from the atmosphere; thus, those portions of the marsh which are rich in foliage have a larger inventory of atmospherically derived radionuclides than poorly vegetated areas. Hypersalinity and the relatively low pH of pore water in marsh sediments increases the mobility of some radionuclides. These processes result in heterogeneous lateral and vertical distributions of atmospherically derived radionuclides and other trace substances in coastal wetlands.

We have examined the relationship between sedimentary processes and faunal characteristics in the James River Estuary by measuring the vertical distribution of radionuclides in 11 sediment cores and relating these profiles to sediment accumulation rates, benthic biological distributions, benthic biomass, and sediment bioturbation. Faunal distribution patterns reflect the response of species to changes in salinity along the estuarine gradient rather than to differences in sediment accumulation rates. Levels of bioturbation could not be easily predicted solely on the basis of faunal characteristics. The results of our studies suggest that the physical processes of erosion and deposition strongly influence the ability of macrobenthos to stir up sediments in this estuary.

¹Sandia National Laboratories, Albuquerque, New Mexico.

²Virginia Institute of Marine Science, Gloucester Point, Virginia.

Sedimentary Rock Program

S. H. Stow, C. S. Haase, K. L. Von Damm, S. Y. Lee,
B. K. Butler, and L. K. Hyder

The Sedimentary Rock Program (SERP) is directed toward the study of shales as host media for a high-level nuclear waste repository. During FY 1986, a national survey of shales was initiated, and work on geochemical-mineralogic characterization of the shales was begun. The survey involved regional hydrologic and stratigraphic-structural characterization of shale-bearing areas in the United States. This survey was halted in the spring of 1986 when the decision was made by DOE not to seek a site for a second repository on an accelerated schedule.

A new SERP subtask related to the geochemistry of groundwaters in shales was begun in 1986. A library search was conducted to find groundwater compositions that have been published. Several analyses of deep groundwaters from the Green River Shale were retrieved; but, overall, very few analyses were reported. The U.S. Geological Survey's WATSTORE data base was the primary source of data. Based on maps, developed for SERP, indicating which shale formations in the United States are deep enough for future study, formations were chosen on a state-specific basis for WATSTORE retrieval. Data for more than 400 analyses of groundwater from shale formations greater than 30.5 m deep were retrieved. Most of the groundwater analyzed came from the Pierre Shale, Green River Shale, and several Gulf Coast formations. Preliminary analysis of the data has shown that the waters have a wide range in composition and are predominantly of the Na-Cl-HCO₃ or Na-HCO₃ type. The pH ranges from 5.9 to 9.4 and is most commonly between 7 and 9. There is no simple correlation between the composition of the waters and the depth at which they occur. Preliminary modeling of the waters has been started to determine if their compositions are solubility controlled with respect to a wide range of mineral phases.

Another activity of SERP involved detailed mineralogical characterization of shales representative of diagenetic and depositional histories to enlarge our understanding of the geochemical behavior of anthropogenic radionuclides in shale strata. These shales included the Chattanooga Shale (carbonaceous), the Pumpkin Valley and Nolichucky Shales (illitic), the Pierre Shale (smectitic), and the Green River Shale (calcareous). Standard chemical digestion and grain-size separation methods were used to isolate size fractions of each sample. X-ray diffraction analysis of dense fractions from the Chattanooga Shale demonstrated the presence of zircon, rutile, and possibly anatase/brookite. Fission track mapping by means of neutron irradiation showed zirconium- and titanium-rich minerals; phosphatic fossils had the highest uranium concentrations. Examination by high-resolution electron microscopy and energy dispersive spectrometry of the Chattanooga Shale showed 10-Å muscovite and illite, 7-Å kaolinite, 14-Å chlorite, and microcrystalline titanium- and iron-rich minerals. Uranium appeared to be associated with microcrystalline heavy minerals, organic matter, and clay minerals as nondiscrete particles.

Nuclear Regulatory Commission High-Level Nuclear Waste Program

G. K. Jacobs, V. S. Tripathi, and K. L. Von Damm

This multidisciplinary program provides technical assistance to the U.S. Nuclear Regulatory Commission (NRC) in its evaluation of information developed by the DOE through its Office of Civilian Radioactive Waste Management. Staff from the Chemistry Division and the Chemical Technology Division are also involved. ORNL provides the NRC with an independent assessment of

the methods, assumptions, and results of DOE research on geochemical processes important to the performance of high-level nuclear waste repositories.

Laboratory studies were initiated to investigate the sorption of radionuclides onto samples of tuff from the candidate site at Yucca Mountain, Nevada. Parameters addressed were (1) use of synthetic groundwater vs actual well water, (2) use of a CO₂ atmosphere for control of solution pH, and (3) mineralogical heterogeneity within individual core samples.

Calculations were made to evaluate the viability of K_d-based contaminant transport models to predict the migration of radionuclides from a repository. Preliminary results suggest that comprehensive hydrogeochemical models (e.g., HYDROGEOCHEM), which explicitly account for important geochemical processes, will significantly improve the accuracy of predictions. K_d-based models, which lump all geochemical processes into a single invariant parameter, the retardation factor, were unable to account for small variations in groundwater chemistry and host-rock mineralogy that can change the effective K_d values by several orders of magnitude.

A workshop was organized and carried out for the NRC and its contractors to help resolve issues related to the modeling and testing of sorption processes. The workshop focused on the level of detail and accuracy necessary to provide defensible predictions of radionuclide transport. The types of tests and data needed to support reliable predictions were also identified.

Key DOE reports on geochemistry were identified, obtained, and input into the Waste Management Document Data Base. Each report is assigned a priority for review and evaluation. Each evaluation, furnished to the NRC, is also included in the record of the document in the data base. This system ensures that information will be available in a form that can be utilized by the NRC during licensing activities.

The Hydrofracture Program

S. H. Stow, C. S. Haase, J. Switek, P. H. Pollard, and H. L. King

In the annual progress report for the period ending September 30, 1985, a number of important issues relating to the hydrofracture program were identified: (1) hydrologic isolation of the injection zone, (2) chemical composition of the groundwaters of the injection zone, (3) possible presence of a usable supply of drinking water under the injection zone, (4) composition of injected wastes, and (5) stability of the injected grout in a saline environment. During 1986, these issues were investigated, and decisions were made regarding the future of the operation. The most significant was a decision not to seek a permit for future injections of liquid waste; DOE was advised to prepare a closure plan for the four hydrofracture sites. It was also decided that a deep well to the Knox Group would not be drilled at this time, and additional deep monitoring wells at the New Hydrofracture Facility were constructed. Preliminary data on the chemistry of the groundwaters from these wells were issued; the data confirm high levels of radionuclides in the groundwater of the injection zone and low levels of radionuclides in waters from the overlying and underlying strata. Because of the construction history of some of these wells, additional sampling is required to confirm the existence of radionuclides in some of these strata.

A draft closure plan for the four hydrofracture sites was issued during the year; this plan is a phased approach toward regulatory closure of the sites. One of the principal phases is site characterization, and preparation of a detailed site characterization plan was initiated. This activity consists of extensive geologic, hydrologic, and geochemical studies of the sites to help address a series of technical issues that have been identified. Work will be undertaken to assess the hydrologic

characteristics of the sites, to determine the extent of present groundwater contamination, to characterize the microstructures and macrostructures that could serve as flow paths for groundwater, to investigate the chemistry of the groundwaters, and to relate site hydrology to regional hydrology.

Hydrostatic Head Monitoring Stations

R. B. Dreier and C. M. Beaudoin

The purpose of the Hydrostatic Head Monitoring Stations is to characterize water table levels in waste management areas in Melton and Bethel valleys. This will provide information on the distribution of hydrostatic heads for different flow systems that have the potential for transporting radionuclides and will supplement geologic characterization studies in these regions.

Each Hydrostatic Head Monitoring Station consists of a cluster of three wells with depths of 120, 60, and 25 m. There is a 6-m open interval at the bottom of each well. During 1986, drilling for the Pits and Trenches Project (three clusters) and the Solid Waste Storage Area 6 (SWSA-6) Project (three clusters plus one 120-m well) was completed. Geophysical logs for each 120-m well were acquired, and the logs were preliminarily interpreted to determine lithologic contacts and fractured zones. Depths for the 60-m wells were targeted for identified fracture zones. The U.S. Geological Survey is responsible for recording the hydrostatic head levels in each of these wells.

Hypercube Parallel Computers in Environmental Research: An Example from Contaminant Transport Simulation

V. S. Tripathi, J. B. Drake,¹ and G. T. Yeh

A hypercube computer is a multiprocessor, distributed memory, message-passing parallel computer. It consists of a host (cube manager) and several "node" processors, which are interconnected in a hypercube topology. Our experience has clearly demonstrated that even primitive hypercubes can be used for solving real-world problems. There is some debate as to whether or not the hypercube architecture is a viable technology. We believe that the demonstrated success of hypercube computers in diverse applications, such as ours, will help end the debate about the future of these machines and provide the impetus for rapid development. Experimental hypercubes comparable in speed to CRAY computers already exist; these point toward the potential for future developments.

To investigate the potential applications for such machines in environmental research, the most computation-intensive segments of a hydrogeochemical contaminant transport model were implemented on a 64-node Intel hypercube. Measured run times for very small to very large chemical problems indicate that the parallel algorithm solves multiple chemical problems in the same time it takes the sequential algorithm to solve one problem. The interface used between the hydrologic and the chemical submodel resulted in natural parallelism of the algorithm and allowed full (100%) utilization of all the hypercube processors. Based on the computational speed alone, the 64-node hypercube appears to be 2 to 3 times faster than a VAX 8600 computer serving a single user.

Work is continuing on further optimization of the contaminant transport model on the hypercube. Two new areas of research have been initiated: (1) development of artificial-intelligence-based expert systems for hydrogeochemical models, and (2) performance of sensitivity analyses for transport calculations. These projects will greatly benefit from concurrent computations on the hypercube.

¹Engineering Physics Division, ORNL.

Solid Waste Storage Area 6 Characterization Studies

E. C. Davis, W. J. Boegly, Jr., R. B. Dreier, D. K. Solomon, S. Y. Lee,
D. A. Lietzke,¹ A. D. Kelmars,² P. M. Craig,³ and D. S. Marshall

Solid Waste Storage Area 6 (SWSA-6) is a 27.5-ha low-level radioactive waste landfill located in Melton Valley, southwest of ORNL. Through 1984, ~29,100 m³ of waste, containing ~250,000 Ci of radioactivity, have been buried at the site (Boegly et al. 1985). In order to ensure that ORNL can continue to operate SWSA-6, it is necessary to establish that the facility is in compliance with existing environmental regulations, especially those dealing with facility closure. Characterization studies were initiated in FY 1986 to (1) assess past performance of the site and (2) provide environmental data in support of overall site closure. These studies include characterization of the site hydrology, soil, and geology, combined with a contaminant pathways study designed to assess potential modes of radionuclide transport.

The SWSA-6 hydrology studies are based on a water balance for the site. Gaging stations constructed on the three tributaries on the site have been recording surface runoff on a continuous basis since June 1985. Direct measurements are also being made of precipitation, soil moisture, water table fluctuations, and groundwater discharge to White Oak Lake. Sampling and chemical analyses of water from water table wells are being used as an indicator of the possible waste source term and the extent of radionuclide migration. Samples collected to date indicate the presence of ³H and ⁹⁰Sr, along with naphthalene, toluene, and other organic compounds.

Geologic characterization included the acquisition and interpretation of deep seismic data, the drilling of a borehole south of White Oak Lake, and a detailed analysis of fracture fabrics in ten shallow trenches. A soil survey of the entire SWSA-6 site was also completed (Lietzke and Lee 1986).

Solid Waste Storage Area 4 Data Package

E. C. Davis and R. R. Shoun²

The ORNL Remedial Action Program has determined, through a review of past environmental studies, that Solid Waste Storage Area 4 (SWSA-4) continually releases radioactivity into White Oak Creek, and thus requires site stabilization and remedial actions, as outlined under Sect. 3004u of the Resource Conservation and Recovery Act. During FY 1986, previously obtained data on the SWSA-4 Waste Area Group were assembled and reviewed. This Waste Area Group includes the 9.3-ha SWSA-4 site, an adjacent abandoned low-level liquid waste transfer line, and the experimental pilot pit area. Results of this review demonstrated that, although a number of studies have been carried out on SWSA-4, data gaps still exist in the following areas: (1) the kinds of contaminants buried at the site, (2) the presence or absence of deep groundwater flow, (3) the relative importance

¹University of Tennessee, Knoxville, Department of Soil Science.

²Chemical Technology Division, ORNL.

³Environmental Consulting Engineers, Knoxville, Tennessee.

of surface vs subsurface flow in contaminant transport, and (4) the likelihood of future subsidence of trench covers. A characterization program to provide this information will be conducted as part of the remedial investigation and feasibility study for this Waste Area Group.

Trace Metal Levels in Pearl Harbor Sediments

T. L. Ashwood, C. R. Olsen, I. L. Larsen, and T. Tamura¹

The U.S. Navy's Inactive Fleet maintains vessels at several locations around the United States. As a result of the Navy's preservation activities, small quantities of paint flakes enter the waters of these harbors. Since marine paint contains trace metals of environmental concern, the commander of the Inactive Fleet requested that ORNL investigate whether these paint flakes were having any discernible effect on trace metal levels in the sediments of Pearl Harbor.

Several long and short sediment cores were obtained from Middle Loch of Pearl Harbor, where vessels of the Inactive Fleet are maintained, and from an area of West Loch, where there have been virtually no naval operations. Sections of these cores were dated, using ¹³⁷Cs and ²¹⁰Pb, and analyzed by inductively coupled plasma and atomic absorption spectroscopy for a complete suite of trace metals.

The results indicated that (1) copper, lead, and zinc were present at elevated levels in recent sediments (however, the increase in these metals began prior to the beginning of Inactive Fleet operations); (2) the trace metal signature (ratios of copper and lead to zinc) was different from that expected for paint, but similar to that expected for sewage; and (3) the trace metal signature in Middle Loch was similar to that in nearby West Loch (Ashwood et al. 1986). For these reasons, it was concluded that the Inactive Fleet operations are not contributing a measurable amount of trace metals to the sediments.

Near the conclusion of the study, the U.S. Environmental Protection Agency (EPA) cited the Inactive Fleet operations in Pearl Harbor for violation of the Clean Water Act due to discharges of paint. The ORNL report was used as the basis for the Navy's response to the EPA's notice of violation.

Forest-Clearing Experiment

R. B. Clapp, N. D. Farrow, and K. C. Dearstone

In humid climates the depth to the water table can be critical to the design and performance of waste disposal trenches, because it is important to maintain an unsaturated zone between the wastes and the more mobile groundwater for effective isolation. In the forest-clearing experiment, the objective is to predict, by computer simulation, the change in groundwater elevation associated with the removal of the forest cover that occurs during site development and to evaluate that prediction by comparison with field measurement. Simulations of the changes in the water budget and the groundwater regime at a test site in the nearby Melton Branch drainage area indicated that a maximum 1.0- to 1.2-m increase in the water table elevation could be expected, primarily due to the decrease in evapotranspiration.

The water table has been monitored at the 1.4-ha test site and in the surrounding area for the past 2.5 years. The test site was cleared of trees and planted to grass in the late summer of 1985.

¹Senior Research Advisor, ESD.

Since then, the water table elevations measured in four wells at the site have exhibited a complex response relative to the expected level (assuming no forest clearing), based on correlations with control wells outside the cleared area. However, during midwinter, there was a clear trend to a lower water table, which is opposite to the original working hypothesis. Water levels fell relative to expected levels by $\sim 0.2\text{--}0.6$ m. The most plausible explanation is that overland flow increased (and recharge to the water table decreased) during winter storms because of a loss in infiltrability associated with the loss of soil macropore structure during clearing. This inference is supported by the increase in the runoff:precipitation ratio. For the period of November 1985 through March 1986, the ratio was 0.59 compared with 0.53 and 0.55 for the same months in 1983–84 and 1984–85, respectively.

Future work will focus on the incorporation of the infiltrability directly into the water budget simulations. At this point, it appears that changes in groundwater elevation during site development cannot be modeled simply by estimating changes in evapotranspiration, but that changes in the soil's physical properties must be considered also.

Development of Waste Disposal Technologies

R. B. Clapp, C. W. Francis, E. C. Davis, N. D. Farrow, and T. Grizzard

Earth Sciences staff have participated in the development and monitoring of a variety of new methods for the disposal of low-level radioactive waste to replace past practices of shallow land burial in unlined trenches. The staff have worked with the Operations Division to design and monitor engineered subsurface structures, usually cylinders [6 m (20 ft) long \times 2.8 m (9.3 ft) outside diameter] buried or formed in place. For each basic unit, the floor is constructed out of concrete, and the walls are coated with sealant. The cylinders are filled with waste, voids are grouted, and the tops are sealed with concrete.

At the Y-12 Plant, a monitoring plan is being developed to measure and analyze emissions from trenches where machine turnings of radioactively depleted uranium will be oxidized and then buried. The plan calls for the collection of data on chemical and hydrologic conditions within the trenches and the surrounding soil. These data will greatly enhance our ability to predict the movement of uranium from older facilities where the chemistry and dynamics of the source term are unknown.

Other projects deal with new configurations for waste disposal units. At the Oak Ridge Reservation, the potential for waste disposal would be greatly increased if the wastes could be placed or buried on hillslopes without increasing the risk of leaching due to lateral groundwater flow. To address this problem, 27 concrete boxes containing 24 m^3 (830 ft^3) of contaminated soil were placed on a concrete pad built in a hillside cut. The monitoring system was designed to collect separately all the vertical seepage that may come in contact with the waste containers and all the lateral seepage that intercepts the perimeter of the facility. The main purpose is to demonstrate the efficiency of the lateral seepage collector.

In a related activity, an aboveground facility capable of storing 850 m^3 ($30,000\text{ ft}^3$) of waste has been designed, and the concrete pad will be constructed in early 1987. The monitoring plan must consider both surface and subsurface movement of leached waste and conditions when the facility is active and afterward when it is covered by an earthen cap. These activities complement work by others within Martin Marietta Energy Systems who are working to reduce the volume and leachability of wastes.

"Bathtubbing" Trenches

D. K. Solomon

Waste trenches in many low-level radioactive waste disposal sites become saturated with water even when the surrounding water table is below the bottom of the trench. This phenomenon has been referred to as "bathtubbing." In order to understand and assess the extent of bathtubbing, several trenches in SWSA-6 have been instrumented with continuous water-level recorders and are being monitored throughout an annual hydrologic cycle. Large-scale hydraulic tests are being conducted by pumping water into several of these instrumented trenches. The observed water levels in and outside of the trench, along with the measured pumping rate, are then used to calculate the hydraulic properties of the trench waste and the surrounding soil.

Two methods are currently being used to estimate the monthly discharge of water from trenches: (1) hydraulic modeling and (2) saltwater dilution. The hydraulic modeling method uses observed water levels and measured hydraulic properties to obtain solutions to the equation of motion for fluids in a porous medium. The saltwater dilution method directly measures discharge by observing the dilution of an injected saltwater solution. Both methods appear to give similar estimates of discharge, which ranged from 0 to 13 m³ for trenches in SWSA-6 during March through July 1986.

The results of hydrologic studies will be combined with investigation of trench leachate geochemistry to provide the basis for pathways analyses. The contaminant source term investigations have employed sampling and analysis of groundwater immediately adjacent to representative trenches. The results show that ³H, ⁹⁰Sr, and several organic compounds are present and must be considered part of the source term at SWSA-6.

Modeling Groundwater Flow and Contaminant Transport

G. T. Yeh and V. S. Tripathi

To simulate the response of waste burial trenches to rainfall events, the FEMWATER computer code (Yeh and Ward 1980) was modified to include the water balance computation for a group of trenches. Using the modified computer code, we performed a preliminary hydrologic simulation of the "49 trench area" in SWSA-6 for the August 16, 1985, storm. The predicted water level in Trench 150 was nearly identical to the measured value. The results of the simulation suggest that (1) the bathtub phenomenon occurs only in the trenches farthest downslope, (2) ~15% of the water entering the trenches comes from the surrounding media, and (3) water from saturated soils surrounding the trenches continues to seep into the lowermost trench even after the rainfall stops. To examine the effect of grouting as a stabilizing measure, a simulation of postgrouting conditions was also conducted. The results indicate that the bathtub effect can be eliminated if the hydraulic conductivity of the trench contents after grouting is equal to or less than that of the surrounding media.

Recently, there has been a sharp increase in the number of computer models aimed at coupling hydrologic transport and chemical interactions of multispecies elements (Jennings, Kirkner, and Theis 1982; Theis, Kirkner, and Jennings 1982; Miller 1983; Morrey and Hostetler 1984; Cederberg 1985). While many of these models can serve as research tools, few existing models can deal with practical problems. The difficulties arise mainly because of inappropriate adaptation of the primary dependent variables in the transport equations and the misuse of numerical schemes to solve

the equations. Consequently, the models suffer from problems such as nonconvergence and excessive run times. The rationale and the means for alleviating these problems have been proposed, and a resulting hydrogeochemical transport model for multichemical components, HYDROGEOCHEM2D, has been developed. Since chemical equilibrium problems are generally posed as nonlinear mass-balance equations, the total concentrations of the various components were naturally chosen as the primary dependent variables in HYDROGEOCHEM2D. To our knowledge, this choice has been made in only one other model (Cederberg 1985). Unfortunately, the Cederberg model employs an explicit iteration scheme and has two major problems: (1) it easily runs into problems with negative concentrations and then fails to recover, and (2) it cannot solve for steady-state problems in one step. Thus, an implicit iteration scheme was employed in HYDROGEOCHEM2D to solve the transport equations. As a result, HYDROGEOCHEM2D provides fast nonnegative solutions and easily handles the full complement of chemical reactions, including complexations, dissolution, precipitation, adsorption, ion exchange, and redox. Another unique feature of this model is its ability to solve for steady-state concentrations in one step. Several example problems have been used to compare the newly developed HYDROGEOCHEM2D with other existing models.

A subregional finite element, block iteration technique developed earlier (Yeh, Hwang, and Cho 1985) has been adapted for the development of three-dimensional finite element models of moisture movement and contaminant transport in saturated-unsaturated subsurface media. Savings of several orders of magnitude in central processing unit storage and time can be realized in dealing with realistic field problems.

References

- Ashwood, T. L., C. R. Olsen, I. L. Larsen, and T. Tamura. 1986. Trace metal levels in the sediments of Pearl Harbor (Hawaii). ORNL/TM-10149. Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Boegly, W. J., R. B. Dreier, D. D. Huff, A. D. Kelmers, D. C. Kocher, S. Y. Lee, F. R. O'Donnell, F. G. Pin, and E. D. Smith. 1985. Characterization plan for Solid Waste Storage Area 6. ORNL/TM-9877. Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Cederberg, G. A. 1985. TRANQL: A Groundwater Mass-Transport and Equilibrium Chemistry Model for Multicomponent Systems. Ph.D. Dissertation. Department of Civil Engineering, Stanford University, Stanford, California.
- Francis, C. W., and M. P. Maskarinec. 1986. Field and laboratory studies in support of a hazardous waste extraction test. ORNL-6247. Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Francis, C. W., M. P. Maskarinec, and J. C. Goyert. 1984. Mobility of toxic compounds from hazardous wastes. ORNL-6044. Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Jennings, A. A., D. J. Kirkner, and T. L. Theis. 1982. Multicomponent equilibrium chemistry in groundwater quality models. *Water Resour. Res.* 18(4):1089-1096.
- Lietzke, D. A., and S. Y. Lee. 1986. Soil Survey of Solid Waste Storage Area 6. ORNL/TM-10013. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

- Lindberg, S. E., and G. M. Lovett. 1985. Field measurements of particle dry deposition rates to foliage and inert surfaces in a forest canopy. *Environ. Sci. Technol.* 19:238-244.
- Lindberg, S. E., G. M. Lovett, D. R. Richter, and D. W. Johnson. 1986. Atmospheric deposition and canopy interaction of major ions in a forest. *Science* 231:141-145.
- Lovett, G. M., and S. E. Lindberg. 1984. Dry deposition and canopy exchange in a mixed oak forest determined from analysis of throughfall. *J. Appl. Ecol.* 21:1013-1028.
- Lovett, G. M., and S. E. Lindberg. 1986. Dry deposition of nitrate to a deciduous forest. *Biogeochemistry* 2:137-148.
- Miller, C. W. 1983. CHEMTRN User's Manual. LBL-16152. Lawrence Berkeley Laboratory, University of California at Berkeley, California.
- Morrey, J. R., and C. J. Hostetler. 1984. Coupled geochemical and solute transport code development. pp. 90-92. IN Proc., Conference on the Application of Geochemical Models to High-Level Nuclear Waste Repository Assessment. NUREG/CP-0062. ORNL/TM-9585. Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Olsen, C. R., I. L. Larsen, P. L. Lowry, R. I. McLean, and S. Domotor. 1986. Chemical forms, mechanisms, and rates affecting the fate of radionuclides in the Susquehanna-Chesapeake Bay system. Final Report to the Maryland Power Plant Research Program, Annapolis, Maryland.
- Theis, T. L., D. J. Kirkner, and A. A. Jennings. 1982. Multi-solute subsurface transport modeling for energy solid wastes, Technical Progress Report for the period September 1, 1981-August 31, 1982, C00-10253-3, Department of Civil Engineering, University of Notre Dame, Notre Dame, Indiana.
- U.S. Environmental Protection Agency (USEPA). 1982. Test methods for evaluating solid wastes, 2d ed. Physical/Chemical Methods SW-846. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Cincinnati, Ohio.
- Yeh, G. T., and D. S. Ward. 1980. FEMWATER: A finite element model of water flow through saturated-unsaturated porous media. ORNL-5567. Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Yeh, G. T., J. C. Hwang, and W. C. Cho. 1985. Subregion iteration of finite element method for large-field problems of groundwater solute transport. *J. Hydraul. Div. Am. Soc. Civ. Eng.* 3:547-551.

3. ENVIRONMENTAL ANALYSES

S. G. Hildebrand

L. J. Allison ¹	M. A. Faulkner	P. A. Lesslie ⁶	J. L. Seiber
C. F. Baes III	M. J. Gentry ³	L. W. Littleton	F. E. Sharples
L. W. Barnthouse	C. L. Glatthaar ⁵	J. F. McBrayer	D. S. Shriner
J. J. Beauchamp ²	J. C. Goyert ³	R. A. McCord ³	L. L. Sigal
C. C. Brandt ³	R. L. Graham	I. L. McCollough	E. D. Smith
J. E. Breck	N. A. Griffith	L. K. McDonald	G. W. Suter II
K. J. Brown ¹	J. W. Hodges ⁶	R. E. Millemann	V. R. Tolbert
G. F. Cada	L. A. Hook ³	R. J. Olson	J. R. Trabalka
D. E. Carpenter ⁴	C. T. Hunsaker	A. Osborn-Lee ⁶	C. S. Tucker
S. M. Chandler ¹	Y. I. Jager ³	C. B. Phillips	R. S. Turner
J. M. Coe	L. J. Jennings	S. F. Railsback	L. D. Voorhees
Z. Combs ¹	P. Kanciruk	R. M. Reed	R. O. Wadlington
R. M. Cushman	G. M. Kondolf ⁷	A. E. Rosen	J. A. Watts
N. S. Dailey ¹	R. L. Kroodsma	M. J. Sale	C. J. Wear ¹
K. C. Dunaway ³	S. P. Ladd ¹	M. S. Salk	J. W. Webb
G. K. Eddlemon	R. W. Lane		

Introduction

The Environmental Analyses Section provides technical expertise to the interdisciplinary environmental assessment activities of Oak Ridge National Laboratory (ORNL). Technical analyses of environmental issues serve as input to decision making at both the Laboratory and the sponsor level. We develop and maintain environmental data bases for assessment purposes. A continuing focus of the Section is the development and application of methods and analytical tools for both quantitative and qualitative evaluation of environmental issues. Analysis activities span the range of spatial scales from individual plant sites to regional and national perspectives. The Section is organized into four groups, which are briefly discussed below.

The principal focus of the Risk Analysis Group is quantification of the hazards associated with technology-related environmental stresses. Major accomplishments in FY 1986 were (1) completion of a data base and statistical models for predicting the effects of toxic contaminants on marine fish and crustaceans; (2) completion of a draft user's manual and collaborative field test of a hazard-ranking system for contaminated sites; (3) publication of a manual describing methods for quantifying the ecological effects of toxic contaminants at the individual, population, and ecosystem levels; and (4) development of scenarios for evaluating the timing and nature of postclosure intrusions on low-level waste burial grounds on the Oak Ridge Reservation. Two new initiatives in FY 1986 were

¹Biology Division, ORNL.

²Engineering Physics and Mathematics Division, ORNL.

³Science Applications International Corporation, Oak Ridge, Tennessee.

⁴Graduate student, University of California, Los Angeles.

⁵Maxima Corporation, Oak Ridge, Tennessee.

⁶Computing and Telecommunications Division, Martin Marietta Energy Systems, Inc.

⁷Graduate student, Johns Hopkins University, Baltimore.

a project on the environmental fate and effects of bioengineered microorganisms used in the treatment of hazardous waste and another on methods for assessing the effects of toxic contaminants on the production and persistence of exploited fish populations.

The two major activities of the Environmental Compliance and Impact Analyses Group in 1986 were (1) providing technical assistance to the U.S. Department of Energy (DOE) and other agency sponsors in complying with federal and state environmental laws and regulations and (2) developing ecological information and analyses for appropriate sections of Environmental Impact Statements (EISs) and Environmental Assessments (EAs) prepared by an interdisciplinary group of scientists at ORNL. Technical assistance provided to DOE consisted of (1) developing and maintaining a system to identify and track new regulatory initiatives that might affect DOE activities, (2) reviewing and providing technical comments on environmental documents prepared on formerly used uranium mill tailing sites and surplus facilities, (3) continuing to provide technical analysis and review of the evaluation and selection of a DOE high-level waste repository, (4) providing technical evaluations of regulatory issues related to management of hazardous waste, and (5) providing background analyses for development of DOE policy in relation to the Safe Drinking Water Act. Technical assistance provided to the U.S. Air Force consisted of overseeing the preparation of guidance on environmental compliance assessments and conducting internal environmental audits for four Air Force bases.

The Group also participated in the preparation of EISs and EAs for a variety of sponsors: (1) completion of the EIS on the cumulative impacts of developing small-scale hydropower projects in the Owens River basin, (2) participation in preparing the draft programmatic EIS on the Chemical Stockpile Disposal Program, and (3) preparation of three EAs on the effects of low-level bomber training routes.

The Regional Resource Analysis Group places primary emphasis on the analysis and interpretation of regional patterns of ecosystems and the processes controlling those patterns. The long-range goal is to utilize an understanding of the fundamental biophysical processes regulating natural systems to analyze the interactions between biological systems and environmental stresses. The basic challenges to regional analyses are to recognize the relevant temporal and spatial scales and to understand the processes regulating the observed landscape pattern in order to predict change in patterns as a function of environmental stress.

Work for the National Acid Precipitation Assessment Program provided a valuable opportunity to apply regional-scale analytical techniques. New initiatives during the past year were (1) evaluating the role of acidic deposition in determining the chemical status of lakes and (2) evaluating the use of remotely sensed imagery in estimating forest productivity. These new projects are highlighted below, along with recent results from the stream survey and direct-delayed response projects. The development and application of the Acid Deposition Data Network, supporting acid deposition assessments, continued in 1986.

The Computer Operations and Data Support Group operates the Environmental Sciences Division (ESD) computer facility, provides research data management and statistical analysis support for ESD and external sponsors, and assists in the development of computer capabilities within the Division. The facility is in its eleventh year of providing the Division with computer capabilities and a high-speed communications link with the ORNL mainframe computer system. Statistical data analysis and programming support continues to be provided by Computing and Telecommunications Division personnel located at ESD and available for both drop-in consultation and long-term collaboration. In addition, the Computer Operations and Data Support Group includes computer analysts

who are assigned to projects that entail major data processing components, such as the Environmental Protection Agency (EPA) National Surface Water Surveys and the ORNL Remedial Action Program.

The Environmental Analyses Section has acquired a geographic information system (GIS) consisting of ARC/INFO (IMSI, Inc.) software and various digitizing, plotting, and work-station hardware. The forte of the GIS is the easy manipulation, display, and analysis of spatial data such as vegetation cover, soil type, or groundwater plumes. One unique feature of the GIS is the ability to extrapolate point data to regions not sampled and to overlay these various coverages to define new relationships. The GIS is a Division resource with applications to environmental assessments, remedial action projects, as well as basic ecological research.

The Environmental Analyses Section also provides staff support to the DOE Hazardous Waste Remedial Action Program and the ORNL Remedial Action Program. All four groups in the Section contribute their strengths to these programs.

Scientific and Technical Analyses of New Rule Making

C. F. Baes III, T. E. Aldrich,¹ W. D. Box,² R. J. Jolley,²
T. D. Jones,¹ B. R. Rodgers,² M. S. Salk, E. D. Smith,
C. C. Travis,¹ and J. W. Webb

An interdisciplinary team from the Environmental Sciences Division, Health and Safety Research Division, and Chemical Technology Division of ORNL is assisting the DOE Office of Environmental Guidance (OEG) in evaluating new rule making developed and proposed by EPA under the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and the Safe Drinking Water Act (SDWA). These rules are of interest to DOE because they could have major impacts on DOE facilities and activities around the country. The ORNL team is composed of scientists who are familiar with waste disposal problems, risk assessment, environmental compliance, and groundwater issues. The team provides OEG with scientific and technical analyses of the proposed rules, which serve as background for (1) understanding the rules and their implications for DOE activities, (2) formulating DOE policy for addressing the issues covered by the rules, and (3) developing DOE responses to EPA.

A rule concerning groundwater monitoring at land-based hazardous waste treatment, storage, and disposal facilities regulated under RCRA is discussed here as an example of the regulatory analysis effort. In this example, EPA proposed to replace the requirements to analyze for all constituents in a large number of hazardous chemicals developed for listing purposes (Appendix VIII to 40 CFR Part 261) with new requirements to analyze for a smaller number of chemicals from a core list developed specifically for groundwater monitoring (Appendix IX to 40 CFR Part 264) when contamination is suspected. The proposed change would eliminate the analysis of constituents for which analytical methods do not exist or are not approved by EPA and should therefore (1) reduce the number of potential controversies, (2) produce a net decrease in the number of chemical analyses required at DOE facilities, and (3) reduce analytical costs. However, the regulatory analysis team felt that the proposed Appendix IX list was substantial and carried a large economic burden, and suggested that alternatives to analysis of Appendix IX constituents as an indicator of groundwater pollution be explored. The alternatives suggested were (1) testing for indicator parameters

¹Health and Safety Research Division, ORNL.

²Chemical Technology Division, ORNL.

such as total organic carbon and total organic halogens, (2) testing for a shorter list of specific chemicals based on the history of operations at a facility, or (3) adoption of other screening tests based on accepted toxicological methodologies.

Cumulative Impacts to Trout of Basinwide Multiple Hydropower Development

G. F. Cada

The Owens Valley of California has a long history of frequent, often bitter conflicts over the allocation of scarce water supplies among competing interests. Because the recent proliferation of small-scale hydropower applications revived these conflicts, the Federal Energy Regulatory Commission asked an interdisciplinary team from ORNL (made up of staff from the Energy Division and ESD) to assess both the individual and cumulative impacts of seven proposed small-scale hydroelectric projects on a variety of target resources. The Environmental Analyses Section staff analyzed the impacts on resident trout populations and riparian resources.

A matrix approach was used to assess the severity of each project's potential impacts on the target resources, measured on a scale ranging from 1 (least severe) to 10 (most severe). As an example, the matrix values for the resident trout populations were based on the reduction in summer and autumn habitat, the winter habitat, and the high-discharge, scouring flows that would result from the operation of each project. The significance of a project's matrix value was evaluated by comparing it with existing hydroelectric projects, for which matrix values could also be calculated and effects on trout populations had been studied.

All but one of the seven projects are expected to cause significant reductions in trout populations if operated as proposed. Estimated reduction of carrying capacity (trout biomass) in the study area attributed to particular projects ranged from 14 to 252 kg; licensing all seven projects could result in a loss of trout-carrying capacity of 700 kg, or 2.6% of the basin's trout resource.

Although none of the impacts predicted for the proposed projects are as large as those associated with major existing facilities in the basin, trout losses comparable to those at existing hydroelectric power plants can be expected because of the additive effects of multiple development.

Environmental Impacts of Low-Flying Bomber Aircraft Along Proposed Air Force Training Routes

R. L. Kroodsmma, R. M. Reed, and G. K. Eddlemon

The U.S. Air Force's Strategic Air Command tests bomber aircraft (the B-52, FB-111, and B1-B) and trains bomber crews for wartime, low-level bombing runs by conducting low-level flights along many designated training routes. New routes must be established occasionally to provide additional training capability and to allow flight crews to navigate through terrain with which they are unfamiliar, thus simulating actual wartime bombing runs.

The environmental impacts of low-level bomber flights along three proposed routes were the subject of three EAs prepared by ESD and the Energy Division. The three proposed routes vary from ~965 to ~1930 km in length, are ~13 km wide, and are located in Upper Michigan and Wisconsin (IR-607), in the Great Plains from New Mexico to Nebraska and Montana (IR-140/428), and in the Southwest from Arizona to Utah (IR-276/276A).

Evaluating the impacts on the many natural resources found along these lengthy routes was a major challenge. Exhaustive field surveys were precluded by the immensity of the area involved.

Our approach was to consult with federal and state natural resource agencies and the open literature in order to determine the scope of the issues and identify sensitive resource locations along the routes, and then visit certain localities identified in the scoping process.

The impact of low-level flight on game animals and threatened and endangered wildlife was considered the primary concern for natural resources. Reductions in wildlife populations were a possibility as a result of (1) wildlife avoidance of habitats (primarily breeding or nesting sites) subjected to repeated aircraft noise, (2) reduced reproductive success of wildlife attempting to breed or nest in noise-affected areas (e.g., disruption of waterfowl and eagle nesting), and (3) decreased survival of big game animals during the winter when they are under nutritional stress and could be severely affected by disturbance. Through discussions with resource agencies, we also identified the location of habitats of important game populations and several endangered species.

Our analysis found that in most cases the proposed routes avoided known wildlife concentration areas (e.g., refuges), as was intended by the Air Force. In Michigan and Wisconsin, however, IR-607 was found to be near several eagle and osprey nest sites, the specific locations of which are not publicized. In subsequent meetings that we proposed with the Air Force and the state and federal wildlife agencies, the proposed route for IR-607 was slightly modified to avoid these sensitive nest sites.

At the completion of the assessment process, we judged that the impacts of low-flying aircraft on game populations and endangered species would be minimal. Upon reviewing our EA on IR-607 and information from the Air Force, the U.S. Fish and Wildlife Service issued a biological opinion, as required by the Endangered Species Act, which agreed with our assessment that the Air Force's proposed action would not jeopardize the existence of endangered species.

Our analysis identified a lack of empirical data on whether wildlife populations would experience long-term declines in noisy areas. This topic will be addressed further in a generic EIS to be prepared for all Air Force low-level training routes in the United States.

Interpreting Forest Biome Productivity Utilizing Nested Scales of Image Resolution and Biogeographical Analysis

R. L. Graham

In a project funded by the National Aeronautics and Space Administration (NASA), ESD and the Illinois Natural History Survey are evaluating the feasibility of using remotely sensed spectral (RSS) data in conjunction with ground-based spatial information on topography and soils [geographic information system (GIS) data] to evaluate forest productivity at a series of landscape scales. The project has three interrelated objectives: (1) to evaluate how and if productivity classification of forest ecosystem complexes can be improved by using fine-resolution RSS and GIS data, (2) to evaluate the feasibility of using fine-resolution RSS and GIS data to quantify forest productivity, and (3) to evaluate the feasibility of stratifying large forest regions into productivity classes with coarse-resolution RSS and GIS data and using fine-resolution RSS data to calibrate and validate those productivity patterns.

Four areas (southern Illinois, Niwot and Indian Peaks region of Colorado, the Adirondack region, and the Great Smoky Mountains National Park) have been selected as intensive study sites for evaluating the utility of fine-resolution RSS data in forest productivity classification and quantification. Paired forest productivity and fine-resolution RSS and GIS data sets are being developed for each of the sites, and preliminary analysis of the relationship between the RSS-GIS data and forest productivity has begun at three of the sites. The universality of the relationship

between RSS-GIS data and forest productivity will be evaluated by comparing not only the observed relationships at the four different sites, but also the observed relationships at the same site on different dates. The Adirondack region will also be used as the study site for evaluating the feasibility of using coarse-resolution and selected fine-resolution RSS data to evaluate forest productivity over a large region.

RSS data has been successfully used to evaluate productivity in agricultural and grassland landscapes, but little work has been done on forested landscapes. This project is part of NASA's effort to expand the utility of RSS data to forested biomes.

Application of Lake Survey Data to Evaluate the Role of Acidic Deposition in Determining the Chemical Status of Lakes

D. E. Carpenter¹ and R. J. Olson

As part of the National Acid Precipitation Assessment Program, the EPA conducted the first phase of the Eastern Lake Survey (ELS-I) in 1984. This primary phase was designed to characterize the current chemical status of a representative population of lakes in the eastern United States. Because of the synoptic design of ELS-I, the data base cannot be used directly to attribute causes for the observed water quality conditions in individual lakes or lake populations. Questions of causality and future trends in surface water chemistry are being addressed in the EPA Aquatic Effects Research Program through detailed analysis of mechanisms acting in a set of representative watersheds.

Notwithstanding the continuing research, the quantitative determination of factors affecting surface water acidification is of immediate concern from a regulatory perspective. Specifically, there is a need to estimate, with the best possible confidence, the degree to which various factors, including atmospheric deposition, may be contributing to surface water acidification. Investigators have proposed several mechanisms to account for surface water acidification, including natural phenomena such as wetland processes, sulfur and nitrogen oxidation, podzolization, and beaver activity. Proposed anthropogenic factors include land-use changes (e.g., lakeshore development and logging), forest fires or their prevention, and the atmospheric deposition of acidifying substances and their precursors.

The Environmental Analyses Section, working with staff of the EPA, has developed a regional analysis tool to estimate the number of acidic lakes surveyed in the ELS-I regions for which atmospheric deposition is the most probable mechanism that could account for an observed acidic status. The analysis tool is in the form of a decision-tree computer program implemented by the Statistical Analysis System (SAS). The decision-tree approach is a screening exercise in which the causes of acidification for individual lakes are progressively eliminated from further consideration if confounding factors (i.e., factors other than acidic deposition) were viable alternative explanations for the acidic status of a lake. These alternative explanations include wetland acidification, mine drainage, lake processes, marine influences, and road-salt runoff.

The results of the decision-tree application indicated that the probable causes of acidification do vary between lakes and regions of the eastern United States. The status of each acidic lake (i.e., the probable cause of acidification) was plotted on regional maps to depict spatial patterns indicating whether alternative mechanisms were associated with well-defined geographic areas.

¹University of California, Los Angeles.

A better understanding of aquatic acidification mechanisms in the future and computer data bases with higher resolution will lead to improved criteria values and more confident explanations for a lake's acidic condition when using this regional approach. Results from the current analysis may prove valuable in targeting future studies at lakes or regions where current acidic conditions lack a causal link with any candidate acidification process or mechanism.

Direct-Delayed Response Project

R. S. Turner, J. C. Goyert,¹ C. C. Brandt,¹
K. C. Dunaway,¹ D. D. Schmoyer,² and J. A. Watts

The EPA is conducting the Direct-Delayed Response Project (DDRP) as part of the Aquatic Effects Research Program of the National Acid Precipitation Assessment Program. For policy planning purposes, the EPA wishes to classify low-alkalinity lakes and streams according to how they respond to acidic deposition. Direct-response systems are defined as those which respond to changes in acidic deposition within three hydrologic response times—less than 10 years for most stream and lake watersheds. Delayed-response systems are those which respond to changes in acidic deposition within 10 to 50 years. Capacity-protected systems are those which have enough buffering capacity that they are not expected to become acidic in less than 50 to 100 years. The overall goal of the project is to estimate the population of lake and stream systems in the eastern United States that can become acidic under current or projected levels of acidic deposition within the next 50 years. The intermediate goals are to characterize the variability of soils and other watershed characteristics across regions with low-alkalinity surface waters, to determine which soil and watershed characteristics are most strongly related to surface water chemistry, and to estimate the relative importance of key watershed processes in controlling surface water chemistry.

One hundred forty-five lake watersheds in the northeastern United States and 35 stream watersheds in the Southern Blue Ridge province have been mapped for soil, vegetation, and bedrock characteristics. The soils in each watershed have been sampled and analyzed for key physical and chemical characteristics. ORNL has developed the DDRP data base, which contains (1) geographic coordinates, (2) the field soil description data, (3) the analytical chemistry data, (4) detailed time-series data for stream or lake chemistry in six of the watersheds, and (5) a synthesized data set consisting of aggregated and calculated data for the individual watersheds as well as linkages to atmospheric deposition data from the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) and stream and lake chemistry data from the National Surface Water Survey. ORNL is collaborating with EPA and other cooperating scientists in three levels of analysis of these data. Level I analyses include statistical characterization of (1) soil and watershed attributes and (2) the relationships between these attributes, atmospheric deposition, and lake or stream chemistry. Level II analyses consist of single-factor projections of how long it will take to exhaust sulfate adsorption and base cation supply capacities in the watersheds. Level III analyses involve running dynamic models [Trickle Down, Model of Acidification of Groundwater in Catchments (MAGIC), Integrated Lake Watershed Acidification Study (ILWAS)] for all or a subset of the watersheds to determine time to acidification considering multiple factors.

¹Science Applications International Corporation, Oak Ridge, Tennessee.

²Computing and Telecommunications Division, ORNL.

Data Management and Analysis for the National Stream Survey

M. J. Sale, J. M. Coe, H. I. Jager,¹ and M. A. Faulkner

The National Stream Survey (NSS) is designed to provide a synoptic characterization of surface water chemistry in regions of the United States that are potentially susceptible to the effects of acid rain. The NSS is funded by the EPA as a part of the Aquatic Effects Research Program of the National Acid Precipitation Assessment Program. ORNL provides data management and analysis support to the survey under an interagency agreement with EPA. This support consists of quality assurance and control of the large NSS scientific data base, statistical programming, and computer-based mapping to display survey results. The target population examined by the NSS is blue-line streams, on 1:250,000-scale U.S. Geological Survey topographic maps, draining watersheds $<155 \text{ km}^2$ ($<60 \text{ mile}^2$) in size.

In FY 1986 a pilot survey was successfully completed in which 61 streams in the Southern Blue Ridge province were sampled (Messer et al. 1986). The results of the pilot survey indicated that under base-flow conditions no target reaches had pH values that were <6.0 , but that a significant proportion of the target reaches had low acid-neutralizing capacity (ANC)—6.3% were $<50 \text{ meq/L}$ and 74.4% were $<200 \text{ meq/L}$. Field sampling of 450 more streams in the eastern United States was also completed in March–April 1986. The preliminary results indicate much higher variability in ANC and pH compared with that observed in the Southern Blue Ridge province. Data base validation, final analyses, and publication of this work will be completed in FY 1987.

Numeric Data Base Established for the Remedial Action Program

L. D. Voorhees and P. Kanciruk

The ORNL Remedial Action Program was established to provide appropriate corrective measures at more than 140 sites that were historically contaminated with radioactive and/or hazardous chemical wastes. Numerous and varied studies are being conducted to achieve this goal; these studies will result in the collection of data on a scale that is unprecedented for the ORNL site. A computerized data base is being developed within ESD's Environmental Analyses Section to effectively and efficiently manage these data.

The data base uses the Statistical Analysis System (SAS) installed on the ORNL tandem IBM 3033 and VAX 8600 computers. The primary strength of SAS is its ability to combine data management capabilities with extensive statistical and graphical capabilities essential for the management of scientific data. SAS is also highly versatile in handling information, both in its data management and report-writing capabilities. Entry of data utilizes focused flexible software to electronically copy and manipulate data produced by a diverse group of investigators. In addition, considerable effort has been given to quality assurance procedures to ensure the accuracy and security of data entries.

After 16 months of operation, the data base contains over 40 data sets covering a wide variety of topics ranging from well-construction parameters to chemical analyses to the abundance of benthic macroinvertebrates. Computer programs are used to electronically transfer analytical data from ORNL's Analytical Chemistry Division DEC-10 1022 files. With the use of this method, more than 30,000 observations of chemical analyses associated with 5 individual characterization or

¹Science Applications International Corporation, Oak Ridge, Tennessee.

contaminant scoping surveys have been obtained. With more than 15 variables for each observation, these data sets alone collectively contain more than 450,000 entries. Procedures were developed to transfer the Division's hydrology data from 1022 files into SAS data sets and also to extract data collected by ORNL's Waste Operations Control Center monitoring efforts. In addition, selected data sets pertinent to the Remedial Action Program have been transferred from ORNL's Department of Environmental Management. Data sets on the construction parameters of 22 water-quality-monitoring wells and 124 piezometer wells have been assembled. The water-quality-monitoring wells were monitored quarterly, and up to 17 rounds of measurements have been recorded for the piezometer wells.

This data base provides a unified repository for all data generated within the Remedial Action Program and provides necessary storage, manipulation, analyses, assessment, display, and report capabilities. Remedial action activities have gained nationwide attention as a result of recent environmental legislation. The organization of the data base for the ORNL site can serve as a model for management of large and highly diverse data sets at other contaminated sites throughout the United States.

Comparative Toxicology for Marine Fish and Crustaceans

G. W. Suter II and A. E. Rosen

Fishes and crustaceans inhabiting coastal marine waters are subject to the effects of a variety of pollutants plus loss of habitat, harvesting, entrainment in water intakes, and natural stresses. Changes in the abundance of these organisms are apparent but difficult to explain. The goal of this project was to collect data on the responses of marine organisms to pollutants and to evaluate the utility of such data for assessing the risks to those organisms due to pollutants.

We developed four data sets for this study. The first is a marine chronic toxicity data set consisting of data from 114 life-cycle or early-life-stage toxicity tests on fish or crustaceans in salt water. The second and third are equivalent sets of chronic data for freshwater fish and the freshwater crustacean *Daphnia*. The fourth data set consists of 2580 acute median lethal concentrations for marine fishes and crustaceans.

The first problem addressed was the need to predict the response of species that have not been tested. We assumed that the response of an untested species was best represented by the response of the tested species to which it was most closely related. We then derived a set of regression equations that could be used to extrapolate between taxa of fish and crustaceans at each taxonomic level. We also derived regressions for the standard marine test species *Mysidopsis bahia* and *Cyprinodon variegatus* as predictors of marine crustaceans and fishes in general. These regression models and their associated variances indicated that extrapolations among marine taxa are about as precise as those previously derived for freshwater taxa, that the standard test species are representative of the higher taxa, and that the responses of crustaceans are considerably less predictable than those of fishes.

The second problem was to determine whether we could identify species that were consistently more sensitive to pollution than the rest of the marine biota. These species would be useful as subjects of monitoring studies in the field and toxicity testing in the laboratory. While no species were consistently most sensitive, mysid and penaeid shrimp were most sensitive on average, and crustaceans were generally more sensitive than fishes.

The third problem was the relative lack of chronic toxicity data for marine organisms. We developed two partial solutions. The first was to predict chronic toxicity from acute toxicity to the same species; this can be done with ± 1 -order-of-magnitude precision. The second solution was to predict chronic toxicity in salt water from chronic toxicity in freshwater. Chronic toxicity thresholds for *C. variegatus* can be predicted from those for the standard freshwater test fish *Pimephales promelas*, and chronic toxicity thresholds for *M. bahia* can be predicted from those for the standard freshwater test crustacean *Daphnia* with ± 1.6 - and ± 1.7 -order-of-magnitude precision, respectively.

The data base and models developed by this project have a variety of uses: they can be used to (1) identify regions where pollutant concentrations may be high enough to harm resources, (2) identify specific pollutants that may be responsible for observed declines in resources, (3) identify species that should be monitored as indicators of pollutant effects, and (4) evaluate the utility of species for use in toxicity testing.

Intruder Scenarios for the Oak Ridge Low-Level Waste Burial Grounds

G. W. Suter II

Because human institutions do not last forever and the barriers constructed by humans will ultimately fail, it is necessary to assume that institutional control of nuclear waste sites will eventually end and that the barriers protecting waste sites will be breached. When this occurs, intruders will enter the sites and engage in various activities that can result in exposure to radiation. The purpose of this study was to create a framework for realistically evaluating the timing and nature of intrusion at six of the existing low-level waste burial grounds and two proposed burial sites on the Oak Ridge Reservation.

The study began with the creation of a taxonomy of intrusion, which consisted of 21 agricultural, residential, natural resource, and miscellaneous uses of the sites that might occur in this region. The problem was divided into two parts: transitions in the sites that change the likelihood of intrusion or exposure and the demand for particular types of land. The relevant transitions were determined to be (1) the end of site maintenance, which results in vegetational succession and degradation of barriers; (2) loss of institutional control, which allows intruders to occupy the sites; (3) degradation of the waste to a state resembling soil, which allows inadvertent excavation of the waste and its use as garden soil; and (4) erosion of the waste cover, which allows direct exposure of the intruders to the waste.

The required characteristics of burial grounds—low slopes and deep soils—mean that there are no strong physical limitations on the potential land uses by intruders. Therefore, in the absence of measures to spoil the sites, land use would be primarily determined by land demand. The two best clues to use of the sites by intruders are the use of the sites prior to federal confiscation and regional trends in land use. Aerial photos taken in 1939 indicate that the sites were used for agriculture, with the predominant uses being pasture or hay and woodlots, followed by abandoned crop land, crop land, and farm buildings and yards. Examination of the trends in land use indicate that agriculture declined until 1970 and has since stabilized. Forest land is also reasonably stable at $\sim 50\%$ of the local land. The primary variable in local land use is urban and other developed uses, which are increasing at $\sim 1.5\%$ per annum. The land-use data suggest that barring constraints or catastrophic occurrences, the sites would be used primarily for pasture in the near term, but residential or commercial development becomes more likely in the next two centuries.

Four general scenarios are proposed for the future of the sites: (1) Control and maintenance of the sites are continued until the radionuclides have decayed to safe levels. (2) Maintenance ends, but control is maintained to the extent of preventing occupation of the sites. Exposure results from recreational use of the sites, particularly by children, and scavenging of artifacts. (3) The sites are not maintained or controlled, but fences and warnings are effective for the population in general. Intrusion is by squatters who are unimpressed by warnings and are anxious to acquire land. (4) The sites are not maintained or controlled and warnings are ineffective, so the sites become part of the regional pattern of land use.

Each of these scenarios is associated with particular activities, which result in different routes of exposure. The report of the study ends with a discussion of the unknowns and the research needed to convert these scenarios into realistic risk analyses. Planned future activities include refinement of the scenarios and preliminary risk analyses.

Strategy and Closure Criteria Development for the ORNL Remedial Action Program: Regulatory Interface

J. R. Trabalka

A review of the institutional, regulatory, and technical considerations associated with stabilization and treatment of contaminated sites was performed. Although some options can theoretically provide a once-and-for-all solution, most realizable options for ORNL sites leave contaminants in place (in situ), potentially isolated by physical or chemical, but more typically, by hydrologic measures. The very low risks to off-site residents posed by current releases from ORNL radioactive and hazardous chemical waste sites, the need to balance these risks against those to workers implementing remedial actions, and the current estimates of the cost differential for stabilization options all strongly favor in situ stabilization over removal and external disposal options. As a result of the dynamic nature of the interactions between the contaminants, the remedial measures, and the environment, in situ stabilization measures are likely to have limited life spans, and maintenance and monitoring of performance become an essential part of the scheme. This need should not be perceived as casting doubt on the effectiveness of the selected option, but rather as a reflection of current reality. Future technology advancements will depend in large part on the ability to recognize the limitations of existing techniques to deal with contaminated sites.

Site closure actions must be affordable, and funding should take into account the need for a phased approach. A program of the magnitude currently envisioned for the ORNL site will probably require a structured federal financing effort, covering a period of decades for planning, technology development, implementation, and evaluation, and a potentially much longer period for necessary follow-up activities such as monitoring and maintenance. The length of formal institutional control over the site and related questions of future uses of the land and water are thus of paramount importance. The unique features of the ORNL site and environs, particularly the dedicated environmental research capabilities, appear to be key ingredients in achieving the very long term institutional control necessary for successful financing and implementation of in situ stabilization. The key issue is whether the principal performance objective for remedial actions (and regulations)—long-term protection of human health and the environment—can be met using this approach.

Regulatory requirements and standards for stabilization and closure are currently incomplete, uncertain, and to some extent negotiable, making it difficult to judge their applicability to the

unique and complex characteristics of ORNL site conditions. Thus, an inescapable summary conclusion is that some formal regulatory interface is necessary to ensure that decisions on closure criteria are based primarily on technical merit and protection of human health and the environment. Adoption of the Resource Conservation and Recovery Act (RCRA) closure performance standard for ORNL sites, coupled with a Remedial Action Program policy directed at (1) near-term control of the critical pathway, represented by surface water releases, and (2) compliance with the intent of the RCRA groundwater protection standard over the long term, by means of site corrective actions, appears to represent a viable approach. A plan for interfacing with regulatory staff from EPA and the state of Tennessee (e.g., through regular meetings and periodic exchanges of information, progress, and ideas) to involve them in the overall strategy development process has been developed.

References

- Messer, J. J., C. W. Ariss, J. R. Baker, S. K. Drouse, K. N. Eshleman, P. R. Kaufman, R. A. Linthurst, J. M. Omernik, W. S. Overton, M. J. Sale, R. D. Schonbrod, S. M. Stambaugh, and J. R. Tuschall, Jr. 1986. National Stream Survey Phase I—Pilot Survey. EPA-600/4-86-026. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

4. TERRESTRIAL ECOLOGY

R. I. Van Hook

M. B. Adams	P. L. Henry	E. G. O'Neill	F. G. Taylor, Jr.
H. Amano ¹	A. E. Hunley	R. V. O'Neill	G. E. Taylor, Jr.
T. J. Blasing	B. Jackson ⁵	M. L. Parker ⁴	R. K. Templeton ¹¹
E. A. Bondietti	P. M. Jardine ²	P. D. Parr	M. L. Tharp ¹²
J. N. Brantley	D. W. Johnson	J. J. Pastor ⁸	P. F. Tiner ¹³
M. Cunningham ²	J. W. Johnston	R. D. Perlack ⁹	D. E. Todd
D. T. Curtin ³	J. D. Joslin ⁷	K. L. Popham	J. L. Trimble
J. H. Cushman	J. M. Kelly ⁷	W. M. Post	A. F. Turhollow ⁹
V. H. Dale	B. C. Lakin	L. R. Pounds ²	D. L. Urban ⁶
D. H. Dawson ⁴	S. G. Lawson	C. Rangarajan ¹⁰	B. T. Walton
T. W. Doyle ⁴	P. A. Layton	J. W. Ranney	R. C. Ward ¹²
N. T. Edwards	R. D. Lomax	B. M. Ross-Todd	K. W. Watson ²
A. R. Ehrenschaft ⁵	R. J. Luxmoore	W. K. Roy	C. R. Wenzel ¹⁴
W. R. Emanuel	L. K. Mann	J. G. Saldarriaga ⁶	D. C. West
C. T. Garten	P. A. Mays ⁷	W. J. Selvidge	A. D. White
C. A. Gunderson	S. B. McLaughlin	A. M. Solomon	G. V. Wilson ²
P. J. Hanson	W. A. McNabb	A. C. Stam ⁶	M. H. Wolfe ⁷
R. B. Harrison	R. J. Norby	S. S. Talmage ⁶	L. L. Wright
J. F. Henrot ⁶			

Introduction

The Terrestrial Ecology Section conducts basic and applied environmental research in support of energy technology development, and has as a major objective the development of a more thorough understanding of the basic processes that govern the transport and effects of materials in terrestrial ecosystems. The Section is organized around three basic areas of research: physiological ecology, biogeochemical cycling, and ecosystem dynamics. Our major emphases are (1) advancing ecosystem theory and understanding, particularly in forest ecosystem growth and production; (2) evaluation of the ecological effects of anthropogenic stresses on natural forested ecosystems; and (3) development of site-specific and global cycles of major nutrients and minor trace elements to serve as a basis for

¹Japan Atomic Energy Research Institute, Tokai-Mura, Naka-Gun, Ibaraki-Ken, Japan.

²University of Tennessee, Knoxville.

³Tennessee Valley Authority, Norris, Tennessee.

⁴Consultant.

⁵Information Resources Organization, ORNL.

⁶Predoctoral student

⁷Tennessee Valley Authority, Knoxville, Tennessee.

⁸University of Minnesota, Duluth.

⁹Energy Division, ORNL.

¹⁰Bhabha Atomic Research Centre, Trombay, Bombay, India.

¹¹Biology Division, ORNL.

¹²Computing and Telecommunications Division, Martin Marietta Energy Systems, Inc.

¹³Health and Safety Research Division, ORNL.

¹⁴Science Applications International Corporation, Oak Ridge, Tennessee.

evaluating future changes. The basic research program is designed to serve as a foundation for the Section's support of the four major thrusts of the Environmental Sciences Division (ESD): acidic deposition, biomass production, hazardous wastes, and global carbon. These studies, which are carried out by Section staff, predoctoral and postdoctoral interns from Oak Ridge Associated Universities and the University of Tennessee, and visitors from outside institutions, ensure continued development of expertise in key disciplinary areas of terrestrial ecology. The Section also utilizes the talents of other ESD sections and other Laboratory divisions in terrestrial research activities. The Section receives support from five primary sponsors: the U.S. Department of Energy (DOE) 61%, the National Science Foundation (NSF) 8%, the Electric Power Research Institute (EPRI) 25%, the U. S. Department of Agriculture's Forest Service (USDA-FS) 4%, and the U. S. Environmental Protection Agency (EPA) 2%, with several smaller projects supported by other federal agencies. To successfully attain the Section's goals, we interact with a large number of outside institutions, including universities, sister national laboratories, the Tennessee Valley Authority (TVA), and the National Park Service. These activities include both collaborative and subcontracted work and account for ~39% of the Section's budget. The Section is responsible for the Division's participation in the National Environmental Research Park (NERP) Program and administers the Oak Ridge NERP. The Oak Ridge NERP is one of five DOE NERPs and is closely tied to both the NSF Long-Term Ecological Reserve (LTER) and the U.S. Department of the Interior (DOI) Biosphere Reserve programs. These programs are providing unique long-term data sets for establishing environmental base lines against which we can measure future change.

The Physiological Ecology Group investigates the mechanisms and processes governing (1) the response of plant and animal systems to natural and anthropogenic stresses and (2) the fate of toxic materials in the terrestrial environment. While the Group's activities range from basic research (stress physiology in woody and herbaceous plant species) to applied research (effects of acidic deposition on forest trees and the suitability of chemical wastes for disposal by land treatment), the perspective of whole-plant and whole-animal physiology is a common denominator among all programs. The diversity of studies integrate both field and laboratory efforts, utilizing the Walker Branch Watershed, the Air Pollution Effects Field Research Facility, forest stands in the southern Appalachians, and the multiple controlled-environment facilities in the Plant Sciences Laboratory. New initiatives in the Group during the past year were rhizosphere physiology, methodologies for mature tree exposure to study the effects of air pollutants on forested landscapes, the fate and effects of hazardous organic chemicals in terrestrial ecosystems, nitrogen dynamics in short-rotation woody biomass plantations, field analyses of the interactive effects of ozone and acidic precipitation on the growth and physiology of loblolly pine, and mechanistic-level modeling of aboveground and belowground processes in woody perennial species.

Major activities in the Biogeochemical Cycling Group during the past year included (1) finalizing the plan for the Integrated Forest Study on Effects of Atmospheric Deposition (IFS), (2) conducting a workshop on soil mineral weathering, (3) initiating ^{35}S cycling research on Walker Branch Watershed (WBW), (4) field and laboratory measurements characterizing nutrient behavior at the Oak Ridge National Laboratory (ORNL) IFS sites, (5) measuring the dynamics of the Chernobyl-derived aerosols, (6) examining ^3H behavior in soil and trees, and (7) performing laboratory studies on SO_4^{2-} adsorption on soils from all IFS sites. The WBW ^{35}S and IFS site research is discussed in more detail below. Management activities for the IFS included developing a weathering subtask and negotiating the participation of two new sites, both funded by the USFS-EPA Forest Response Program.

In our research on developing new applications for radionuclides as tracers of environmental processes, we have been able to isolate and measure natural ^{35}S in soil solutions from the Great Smoky Mountains National Park. A study of tritium behavior in the terrestrial environment on the ORNL reservation has shown positive correlations between tritium concentrations in surface air and in surface soil and negative correlations between tritium concentrations in surface air and relative humidity.

Laboratory support of the IFS included an evaluation of the sulfate-retention properties of soil samples from most of the participating sites, which have differing soil and forest types, atmospheric deposition histories, and physiographic locations. The soils varied widely in SO_4^{2-} adsorption capacity: several soils were oversaturated with respect to 0.25 mM CaSO_4 and released SO_4^{2-} , whereas others retained as much as 4 mmol/kg of SO_4^{2-} at that concentration. Finally, we have completed a 2-year study on the aerodynamic size relationships between natural airborne radioactivity (^{214}Pb , ^{212}Pb , ^{210}Pb , ^7Be , ^{35}S , ^{32}P) and sulfate. The Chernobyl accident produced a unique atmospheric plume of labeled submicron aerosols, which were also examined. Collectively, these studies have given us new insights into how aerosols grow in the atmosphere and have shown that a significant fraction of sulfate aerosols may grow in the plumes rather than in background air after dilution.

The primary focus of the Ecosystem Dynamics Group is developing a basic understanding of forest systems through field studies as well as mathematical simulations. Ecosystem theory and stand-growth models are being used to study forest succession in temperate and tropical forests. Areas of research in model development include sensitivity and uncertainty analysis of forest succession models and investigation of methods of applying forest models to landscapes. The application of models is focused primarily on determining the effects of CO_2 -induced climatic change. Ecosystem research is continuing in the areas of hierarchy theory and organization, error analysis, spectral analysis, and landscape patterns. Work is also progressing in our attempt to detect a change in wood mass through the use of image analysis and X-ray densitometry. New initiatives in the Group include incorporating tree physiology into forest models, landscape dynamics studies, anatomical studies of wood structure, and succession of tropical forests during the Holocene.

During the past year, the global ecology activities of the Ecosystem Dynamics Group focused on understanding the role of terrestrial ecosystems in the earth's major dynamic systems. Climate and biogeochemical cycles are the most important of these. The Group assembles data, conducts specialized field studies, and develops models to address a number of scientific issues. The broad objective of this work is to develop capabilities to analyze global-scale responses to perturbations in terrestrial ecosystems such as land use or climate change. Work in the last 2 years focused on the causes and rates of increase in the levels of atmospheric CO_2 and on the linkages between major global cycles that complicate carbon cycling. The role of trace gases and the broad-scale impacts of climatic change were also considered. Although the Group's research focuses on large spatial scales, a substantial range of time scales is involved in global ecological studies. Theoretical work and methods development are required to ensure that models and data analyses properly treat scaling variations and avoid inconsistencies.

In the following paragraphs, we highlight recent activities in physiological ecology, biogeochemical cycling, and ecosystem dynamics as these theme areas relate to pertinent environmental problems we face today. Contributions of Section staff to the Biomass Production Program and the Carbon Dioxide Research Program (formerly DOE Global Carbon Cycle Program) appear in Sects. 5 and 6 of this report. Our project research is designed to meet the specific needs of sponsors and at the same time provide an opportunity to improve our understanding of the basic ecosystem processes that govern the response of terrestrial systems to natural and anthropogenic stress.

Physiological Ecology

Stress Physiology in Terrestrial Vegetation: The Physiological Site of Ethylene Action in Carbon Dioxide Assimilation (G. E. Taylor, Jr., and C. A. Gunderson)

Terrestrial vegetation responds to a variety of environmental stresses and endogenous signals, and two of the most sensitive physiological processes where such responses can be seen are foliar carbon dioxide assimilation and transpiration. Recent hypotheses for chronic stresses of anthropogenic (e.g., air pollution) and natural (e.g., drought) origin propose a common chemical signal, or growth regulator, which is elicited internally by many different stress agents and which controls the rates of carbon gain and water use. While the role of one such regulator—abscisic acid—is documented to mediate drought-induced changes in foliar gas exchange, our knowledge of the role of other regulators is far less substantial. Theoretically, the case for ethylene is particularly promising in light of its documented production in foliage experiencing stress and the observation that both carbon gain and water use are responsive to ethylene. The objective of the current study was to investigate the physiological site of ethylene action through manipulative experiments that identified the degree to which stomatal and nonstomatal processes limit carbon dioxide assimilation in soybeans (*Glycine max*). The studies were conducted in the Air Pollution Exposure Facility in the Plant Sciences Laboratory and involved the use of a remotely operated single-leaf cuvette.

Elevated levels of ethylene influenced both the stomatal physiology and the leaf's intrinsic capacity for assimilating carbon dioxide. While both processes responded in synchrony, the stomatal response was of far greater magnitude than that of assimilation. In partitioning the limitations imposed on carbon dioxide assimilation, the stomatal component was not a major contributor, accounting for only 16 and 4% of the total in the controls and the ethylene-treated plants, respectively; the balance was attributed to nonstomatal or chloroplastic processes. Consequently, the pronounced decline in carbon dioxide assimilation rates in the presence of ethylene was due more to a loss of the chloroplast's assimilatory capacity than to the reduction in the conductivity of the stomata. Analyses of the efficiency of the light-conversion process, using nonintrusive whole-plant techniques, indicated a 50% reduction in the ability of the chloroplast to convert light to chemical energy (Fig. 4.1).

These data indicate that while ethylene can effect marked changes in both carbon gain and water use, the responses are mechanistically independent. The demonstration that stomatal physiology is a minor contributor to the rates of carbon dioxide assimilation departs significantly from the more traditional role attributed to stomata. The observation that ethylene action in carbon dioxide assimilation does not originate in the stomata supports the hypothesis that the growth regulator is involved in mediating the effects of different physical and chemical stresses on carbon gain in terrestrial vegetation.

Symbiotic Activity in Woody Plants Stimulated by Atmospheric Carbon Dioxide Enrichment (R. J. Norby, E. G. O'Neill, and R. J. Luxmoore)

Symbiotic relationships between plant root systems and soil microorganisms are an important aspect of how plants in their native habitats acquire the environmental resources necessary for growth. Prominent among such symbioses are root nodule formation in association with nitrogen-fixing bacteria in the soil and the mycorrhizal relationships between roots and soil fungi. Both of these relationships depend on photosynthate produced by the host plant and might therefore be more vigorous when the concentration of carbon dioxide in the atmosphere increases. Stimulation of

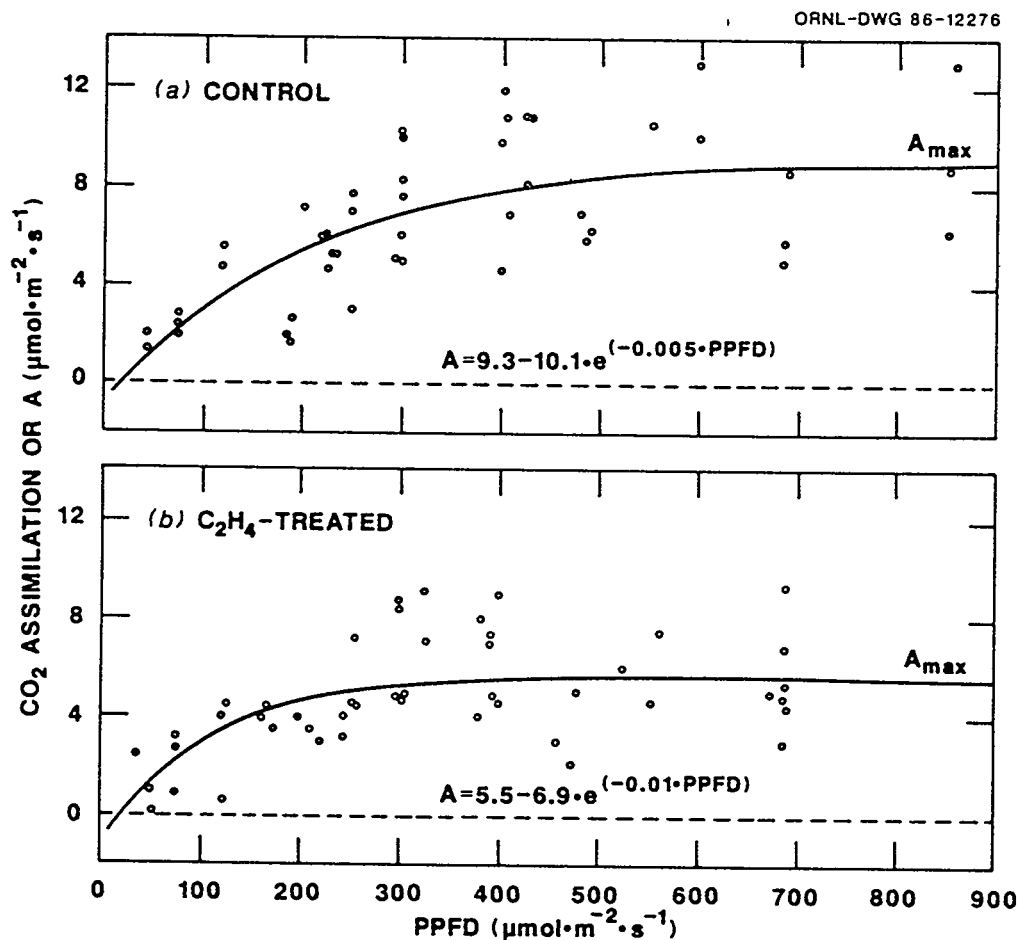


Fig. 4.1. The carbon dioxide assimilation rate in soybeans (*Glycine max*) as a function of irradiance (PPFD or photosynthetic photon flux density) in (a) control plants and (b) plants treated with ethylene (C₂H₄). The parameter A_{max} is the estimated maximum carbon dioxide assimilatory capacity at saturating irradiance. This maximum in ethylene-treated plants is only 50% of that in control plants and indicates a marked effect of ethylene on the plant's photochemical efficiency.

symbiotic activity in the rhizosphere of woody perennial plants could increase the availability of critical inorganic nutrients in infertile forest soils, and may be a prerequisite for sustained growth in trees in response to carbon dioxide enrichment of the atmosphere.

Seedlings of four species of nitrogen-fixing trees were used to study whether nodulation and symbiotic nitrogen fixation in woody plants are stimulated by carbon dioxide enrichment. *Robinia pseudoacacia* (black locust) is a legume that forms nodules in association with soil bacteria in the genus *Rhizobium*. *Alnus glutinosa* (black alder), *Alnus serrulata* (hazel alder), and *Elaeagnus angustifolia* (Russian olive) are actinorhizal species that nodulate with the actinomycete *Frankia*. Enrichment of the atmosphere to 700 $\mu\text{L CO}_2/\text{L}$ increased nitrogen fixation in the woody plants in similar fashion to the increases in nitrogen fixation reported for annual crop plants such as soybeans, alfalfa, and peas grown in a similar CO₂-enriched atmosphere. The physiological basis for the effect was increased nodulation, which was attributed to both a uniform whole-plant response to carbon dioxide enrichment as well as a specific stimulation of nodulation relative to plant dry

weight. The increase in nitrogen fixation and its associated carbon cost did not prevent a substantial plant-growth response to carbon dioxide enrichment, and the increases in growth occurred despite probable nitrogen and phosphorus deficiencies. It is hypothesized that greater increases in nodulation and nitrogen fixation would occur under conditions of greater phosphorus availability. If the responses to elevated carbon dioxide observed in the seedlings in this study are comparable to the responses of larger nitrogen-fixing trees, we can expect growth, nitrogen fixation, and the contribution to available nitrogen pools to increase as the carbon dioxide concentration in the atmosphere increases.

Mycorrhizal responses to carbon dioxide enrichment were examined in white oak (*Quercus alba*) seedlings grown in pots containing forest soil colonized by native fungal species. Beginning at 12 weeks, seedlings grown in an enriched atmosphere (700 $\mu\text{L CO}_2/\text{L}$) had a significantly greater proportion of short roots that were colonized by mycorrhizal fungi than did seedlings grown in ambient carbon dioxide; this difference persisted for 24 weeks. As with earlier experiments with shortleaf pine (*Pinus echinata*), the increase in the number of mycorrhizae was apparent before any difference in biomass was detected, which suggests that initially photosynthate was preferentially allocated to establishment of the symbiosis. The final dry weights of seedlings grown in elevated carbon dioxide were 56% greater than those of seedlings grown in ambient carbon dioxide; the dry weights of the roots increased 91%. In a nutrient-limited system, it is hypothesized that the proportion of a seedling's short roots that are colonized by mycorrhizal fungi affects nutrient acquisition by increasing the surface area for nutrient uptake and delaying the senescence of short roots. Greater mycorrhizal density and increased first-year root growth in an atmosphere enriched with carbon dioxide may enhance nutrient acquisition and thus support further biomass increases.

Biogeochemical Cycling

A Preliminary Evaluation of Chernobyl-Derived Radioactivity Measured in Oak Ridge, Tennessee, May 7 to June 3, 1986 (E. A. Bondietti, J. N. Brantley, I. L. Larsen,¹ R. D. Lomax, C. Rangarajan, and J. S. Eldridge²)

On April 26, 1986, an accident at the Chernobyl nuclear reactor complex in the Soviet Union released large amounts of radioactivity to the troposphere. Fission products from the accident were first measured in Scandinavia on April 28. On May 7, after a 24-h air sample did not show anthropogenic radioactivity, two high-volume cascade impactors were set in operation to measure the aerosol size distribution of the fission products when they mixed into the boundary layer in East Tennessee. One impactor was operated with a charcoal-impregnated glass fiber final filter, and one was operated with a normal glass fiber final filter. It was anticipated that only the fission products which had volatilized from the reactor core would be transported via the free troposphere to Oak Ridge and that, except for ^{131}I , their size distributions would be the same as those for ^7Be and ^{210}Pb but larger than that for ^{212}Pb . The size distributions and growth rates of these natural isotopes have been examined extensively over the past year. The significance of aerosol ^{131}I was of particular interest, since its contribution to the ^{131}I release in the Windscale accident was never determined.

Iodine-131 was first detected in Oak Ridge on May 10; on May 16 the cascade impactors were stopped. From May 20 to 23 and from May 29 to June 3, additional impactor measurements were

¹Earth Sciences Section, ESD.

²Analytical Chemistry Division, ORNL.

made. On May 28-29, two high-volume air samplers were operated for 48 h as part of a study on following aerosol residence times using ^{210}Bi : ^{210}Pb dating. The fission products were analyzed after the removal of ^{210}Pb . Precipitation on May 12, 18, and 23-27 was also measured. Perimeter air samples for the 16th and 17th of May were obtained in order to determine isotope ratios between the 16th and 18th. The samples were examined with coaxial and well-type intrinsic germanium detectors in low-background shielding. All isotope ratio information discussed below refers to measurements decay-corrected to May 16.

From the distributions found on the normal impactor, the activity median aerodynamic diameters (AMADs) for the May 7-16 air sample were calculated. The AMADs for ^{134}Cs and ^{137}Cs were the same ($0.4\text{ }\mu\text{m}$), and those for ^{103}Ru and aerosol ^{131}I were slightly smaller ($0.37\text{ }\mu\text{m}$). By comparison, natural ^7Be had an AMAD of $0.38\text{ }\mu\text{m}$, and 10.6-h ^{212}Pb , whose AMAD reflects very recent condensation, had an AMAD of $0.18\text{ }\mu\text{m}$. Less than 2% of the fission products and ^7Be were found to have AMADs above $4.2\text{ }\mu\text{m}$. This is typical for condensation-derived aerosols.

The aerosol-associated ^{131}I was estimated to be <20% of the total ^{131}I , since the high-volume charcoal filter did not retain all of the gaseous ^{131}I . The chemical forms of ^{131}I in the <0.41- and 0.41- to $0.73\text{-}\mu\text{m}$ ^{131}I aerosol fractions were subsequently evaluated by radiochemical methods previously used on ^{131}I derived from weapons tests. Most of the aerosol ^{131}I was soluble in 0.01 M NaOH, and 20% separated as I^- or I_2 . No ^{131}I precipitated with IO_3^- (some ^{103}Ru did). By contrast, weapons-derived ^{131}I was usually not as leachable, and the leachable ^{131}I always showed significant quantities of $^{131}\text{IO}_3^-$. The 0.41- to $0.73\text{-}\mu\text{m}$ size fraction yielded similar results for total inorganic iodine.

The May 13 shower, collected with a large-surface-area collector, contained ^{137}Cs and ^{103}Ru at the same activity ratio as measured in air. On the weekend of May 17, a significant change in the isotope picture occurred. Precipitation from a convective storm on May 18 gave an isotope spectrum enriched in ^{140}Ba , ^{131}I , and the ruthenium isotopes relative to radiocesium. The May 20-23 impactor sample, the May 23-27 precipitation sample, and the May 28-29 air sample (with the exception of ^{131}I , which was not found after ^{210}Pb removal) also showed the change in ratios. The May 17 perimeter air sample, however, still reflected the conditions present during the first impactor sampling (through May 16). The May 20-23 air sample showed that ^7Be had increased (from a fairly typical value for springtime) by a factor of 1.7, indicative of significant input of upper tropospheric air during the convective period. Fission products also increased by similar amounts over the level of the previous week. By May 29, however, air concentrations had dropped much below those found during the period of May 10-16. These findings are interpreted as indicating the existence of two "clouds"—one at low altitude and mixing into the boundary layer by subsidence and a second one brought to the ground by convective mixing associated with the May 18th storm. Washout calculations indicated that at a minimum, 40% of the air scavenged from May 23 to 27 was contaminated.

The AMADs determined from the May 20-23 impactor measurements were ^{137}Cs , $0.48\text{ }\mu\text{m}$; ^{134}Cs , $0.43\text{ }\mu\text{m}$; ^{103}Ru , $0.45\text{ }\mu\text{m}$; ^{106}Ru , $0.44\text{ }\mu\text{m}$; ^{131}I , $0.32\text{ }\mu\text{m}$; ^{140}Ba , $0.45\text{ }\mu\text{m}$; and ^7Be , $0.39\text{ }\mu\text{m}$. Thus, while ^7Be remained essentially the same, the sizes of the other nuclides (except ^{131}I) had increased. For example, ^{103}Ru was smaller than ^7Be in the first sample but larger in the second sample. The ^{137}Cs AMAD was the largest, although local soil contamination near the sampling site may have biased this value, even though sampling over the last year has not shown this amount of resuspension. The small ^{131}I size distribution is unexplained, but like the first < $0.41\text{-}\mu\text{m}$ fraction, 20% was present as I_2 or I^- . No IO_3^- was found.

In addition to these isotopes, ^{136}Cs was identified on submicron aerosols. While the relative air concentrations cannot be used to evaluate the time course of the accident, isotope ratios are more

definitive tracers of different core conditions, since ruthenium and barium volatilize under different conditions than cesium or iodine. It is quite interesting that barium and ruthenium are enriched in the later samples. There is also evidence for poorly soluble cesium and ruthenium (not beryllium or iodine), suggesting early condensation with other nonradioactive volatiles originating from the reactor's core.

Subsurface Transport Project (R. J. Luxmoore, R. S. Turner, R. W. Arnseth, K. W. Watson, R. R. Turner, G. R. Southworth, and R. C. Ward)

Field, laboratory, and computer modeling investigations of the effects of macropore and soil variability on water and solute transport in a deciduous forest were carried out for two contrasting watershed sites on the Oak Ridge Reservation: the Walker Branch Watershed, which has a deep soil profile (30 m), and the Melton Branch Watershed, which has a shallow soil profile (3 m).

Watershed Chemical Characterization. The cation exchange capacity and pH of the bulk soils were found to account for 75% of the variability in bulk soil manganese adsorption. The mean manganese adsorption was twice as high for Melton Branch Watershed (MBW) soils as for Walker Branch Watershed (WBW) soils. Amorphous manganese oxides increased in concentration with depth in MBW soils, but decreased with depth in WBW soils. Scanning electron micrographs showed distinct coatings of manganese on macropore surfaces and bands of manganese in peds of MBW soils, but very low concentrations and a uniform distribution of manganese in WBW soils. Drainage collected from subsurface weirs in WBW was 10 times more concentrated in manganese and more acidic than that collected from MBW. These results suggest that differences between the two watersheds in bulk soil manganese adsorption alone cannot account for differences in manganese mobility.

Soil Macroporosity. The differences in infiltration rates under ponded conditions (all pores conducting water through the soil) and under tension of up to 1.5 kPa (large pores excluded from the flow process) were used to estimate the macroporosity of the surface soils of the two experimental watersheds. The mean ponded infiltration rate of 16.7 m/d at MBW was higher than the 11.1 m/d value for WBW; however, the infiltration rates under tension control were very similar at both watersheds. Soil macroporosity was very low ($<0.001 \text{ m}^3/\text{m}^3$) at both watersheds, but was sufficient for conducting large quantities (73%) of ponded water through the surface soil.

Chemical Adsorption on Macropore Wall Coatings. Organic (root-derived) and mineral materials coating the walls of large soil pores and channels were collected, and the adsorption characteristics for cadmium and manganese were determined. Such measurements were also made with the bulk soil adjacent to the macropores. Chemical adsorption was higher (10 times higher for cadmium, 2 times higher for manganese) for the organic coatings than for the bulk soil, whereas the mineral coatings on macropores had adsorption characteristics similar to those of the soil matrix. Greater chemical retardation is expected through old root channels than through macropores without organic materials.

Chemical Transport Through Soil Columns with Macropores. The migration of tritiated water, ^{22}Na , ^{85}Sr , and ^{65}Zn through an intact soil column characterized by high hydrodynamic dispersion was observed under ponded flow conditions. The elution of the tracers was simulated with an advection-dispersion model and a two-region/two-site transport model. The advection-dispersion model represented the elution curve of tritiated water well, but the two-region/two-site model was required to describe the elution of the ^{22}Na tracer from the soil column. The ^{85}Sr and ^{65}Zn were strongly adsorbed and were retained by the soil column. These ions did not appear in the effluent,

despite high hydrodynamic dispersion, which resulted in the nearly immediate appearance of tritiated water in the effluent.

Simulation of Soil Variability Effects on Subsurface Flow. A three-dimensional hydrologic model was set up to represent a 30° hillslope with four patterns of soil variability. The mean and variance of the soil's hydraulic properties, defined in terms of scaling factors, was the same in all cases, with one case having a random spatial distribution and the other having a spatially correlated distribution of soil properties. The subsurface outflow resulting from a rainfall intensity of 10 mm/h for 4 h occurred at a greater rate from the hillslopes with spatially patterned soil distributions. The random distribution of soils favored the interaction of dissimilar types of soil (coarse- and fine-textured) with differing water capacities, resulting in a lag in hillslope outflow relative to the hillslopes with spatially correlated soil distributions.

Radiosulfur Cycling Research at Walker Branch Watershed (C. T. Garten and R. Lomax)

Two red maples (*Acer rubrum*) and two yellow-poplars (*Liriodendron tulipifera*) on Walker Branch Watershed were labeled with ^{35}S (87-d half-life; maximum beta energy 0.167 MeV) by stem-well injection in late June 1986 to determine (1) the extent of foliar leaching of biologically incorporated sulfur, (2) the degree of transformation and volatilization of sulfate-sulfur by trees, and (3) the extent of sulfur turnover by tree roots. One tree of both species studied was girdled to prevent downward translocation of the injected ^{35}S . The girdled trees were harvested in October, and measurements will be continued on one poplar and one maple tree (not girdled) into the dormant season.

From measurements of ^{35}S concentrations in leachates and measurements of the total volume of throughfall and stemflow beneath the girdled maple, it was determined that a total of 0.012 μCi was leached from the tree in stemflow and 0.11 μCi was leached by throughfall during the 89-d experimental period. These amounts corresponded to 0.7 and 8.2%, respectively, of the total ^{35}S in maple foliage and <0.06% of the amount injected. Only 0.33% of the ^{35}S in the girdled maple's foliage was leached per centimeter of rainfall. About half (0.055 μCi) of the total ^{35}S leached from the tree in throughfall was leached by rainfall during the first week after labeling. Therefore, the freshly added ^{35}S appeared to be more leachable from maple foliage than the ^{35}S which had aged in the leaves for several weeks.

The concentrations of ^{35}S in tree leaves after labeling increased with time and reached 50% of their maximum value within 2 weeks. More ^{35}S was extractable from poplar leaves than from maple leaves using 0.01 N HCL; however, chromatography of the poplar leaf extract on Biogel P-2 indicates that ^{35}S in the extract does not behave like sulfate-sulfur. Concentrations in the trunk 0.5 m above the stem well decreased, whereas concentrations in small stems (<1 cm diam) increased during the study.

At harvest, maple leaves, stems and branches, and trunk contained 3.3, 6.6, and 110.6 μCi , respectively. Nearly 65% (64 μCi) of the ^{35}S in the tree at harvest was associated with the 4.9-kg portion of trunk which bore the injection well. At present, ~31% of the initial ^{35}S in the girdled maple tree is unaccounted for and may represent either sampling error, measurement error, or transformation and volatilization of ^{35}S from the tree foliage (Table 4.1). Further measurements are being made on this single tree for the purpose of quality assurance and to determine the extent of sampling error contributing to the portion of ^{35}S that is unaccounted for. Some researchers argue that volatilization losses from trees can account for a major fraction of the apparent net accumulation of sulfate-sulfur by forest ecosystems.

**Table 4.1. Activity balance for ^{35}S -labeled red maple tree
89 d after stem-well injection**

Item	^{35}S (μCi)	Percent injection
Injection well (not assimilated)	5.4	3.0
Tree		
Leaves	3.3	1.8
Branches and stems	6.6	3.6
Trunk	110.6	60.8
Litterfall	0.1	0.05
Leaching		
Throughfall	0.1	0.05
Stemflow	0.01	0.01
Unaccounted for (Volatilization, sampling error)	56	30.7
Total injected	182	100

Integrated Forest Study (D. W. Johnson, D. E. Todd, K. C. Dearstone, R. B. Harrison).

The Oak Ridge National Laboratory is responsible for the operation of four Integrated Forest Study (IFS) acid deposition research sites: a loblolly pine (*Pinus taeda*) site at ORNL, two red spruce (primarily *Picea rubens*, with a minor component of Fraser fir, *Abies fraserii*) sites, and one beech (*Fagus grandifolia*) site near Clingmans Dome in the Great Smoky Mountains National Park (GSMNP). The preliminary results of our research show that sulfate is the major anion in soil solutions from the loblolly pine site, indicating that leaching processes at this site are dominated by atmospheric sulfur inputs. Soil solutions are near pH 6, and the cationic component consists primarily of calcium and magnesium, with lesser amounts of potassium and sodium and only trace amounts of aluminum. Since the soils from this site are moderately acid (pH 4.4 in 0.01 M CaCl_2 and 70% base saturation by the sum-of-cations method), this cation composition in the soil solution is as expected.

In contrast to the loblolly pine site at ORNL, the anionic component of soil solutions from the GSMNP sites (both spruce and beech) is dominated by nitrate. Since nitrate concentrations increase dramatically from throughfall to forest floor solutions, we infer that nitrate is produced within the soil by nitrification. Both hydrogen and nitrate ions are produced during the nitrification process (i.e., nitric acid is produced); thus, nitrification within the soil is the dominant mechanism for nitrate leaching and acidification at these sites. The soil solutions from these three sites are much more acid (pH 3.5–4.5) than those from the loblolly pine site, and aluminum is often the

dominant cation. Since the soils from all three of the GSMNP sites are extremely acid, with pH values of <4 in $0.01\ M\ CaCl_2$ and base saturation of $<5\%$ (by the sum-of-cations method), the presence of large amounts of aluminum in the soil solution is as expected. We do not yet know the reason for the high rates of nitrification and nitrate leaching at the GSMNP sites. Since nitrogen deposition is expected to be relatively high at these sites, it is very doubtful that the current levels of atmospheric nitrogen inputs can account for the very high rates of nitrogen loss through nitrate leaching. This leaves a situation in which soil nitrogen is very likely being depleted currently. The reasons for this depletion could include disturbance (e.g., forest decline or dieback due to balsam woolly aphid attacks in the fir component of the spruce sites, hog rooting in the beech site) or a general increase in the decomposition of organic matter in the soil and on the forest floor perhaps induced by a change in microclimatic conditions. These hypotheses are currently under investigation.

These initial results suggest that we must pursue very different lines of investigation in determining the effects of atmospheric deposition at the low-elevation loblolly pine site vs the high-elevation spruce and beech sites. In the former, we must concern ourselves with the potential long-term effects of accelerated leaching rates on soil acidity and fertility. This will involve a careful analysis of the pools and fluxes of calcium, magnesium, and potassium in these ecosystems. In these cases, we must be concerned with the short-term effects of elevated aluminum in soil solutions (e.g., toxicity effects on tree roots and possible transport to streams).

Ecosystem Dynamics

National Environmental Research Park (P. D. Parr and L. R. Pounds)

The Oak Ridge National Environmental Park (NERP) has been active in working with the Tennessee Department of Conservation (TDC) and the DOE Oak Ridge Operations Office in the placement of eight sites on the Oak Ridge Reservation in the Tennessee Natural Areas Registry. This agreement, signed in January 1986, between the TDC and the DOE Oak Ridge Operations Office assigns responsibility to the Oak Ridge NERP for coordinating interactions with TDC and for implementing federal and state regulations concerning rare plants and their habitats on the Oak Ridge Reservation. The Tennessee Natural Areas Registry is a land protection tool which was established by the Natural Areas Preservation Act of 1971. It is TDC's primary tool for protecting non-state-owned lands of natural significance. The primary emphasis in natural area registration is on those areas which support populations of endangered or threatened plants or animals or old-growth forests.

The following eight sites on the Oak Ridge Reservation have been placed in the Natural Areas Registry because of their rare plant populations or unique plant communities:

1. Campbell Bend/Crowder Cemetery Barrens — This area includes bluffs along the Clinch River that support a population of the false foxglove (*Aureolaria patula*), which is on the state list as threatened and under status review for federal listing. It also contains a cedar barrens habitat with an unusual association of plant species, including tall larkspur (*Delphinium exaltatum*), which is listed as endangered in Tennessee, prairie goldenrod (*Solidago ptarmicoides*), which is listed by the state as threatened, and auricled gerardia (*Agalinis auriculata*), which is listed by the state as endangered and is also under status review for federal listing.

2. and 3. Poplar Creek Hemlock Bluffs — Stands of Canada hemlock with a rhododendron understory occur along Poplar Creek on McKinney Ridge and also on Black Oak Ridge. Though no

rare species are currently known to occur in these stands, these hemlock-rhododendron communities are quite unusual on the Oak Ridge Reservation.

4. Walker Branch Embayment "Barren" — This is not a true barren, but rather a rocky wooded area with a sparse oak-cedar overstory. In the herbaceous layer of this forest, there is a population of tall larkspur (*Delphinium exaltatum*), which is listed as endangered by the state.

5. Bearden Creek Bluff — On the bluff near the confluence of Bearden Creek and the Clinch River there occurs a relic stand of northern white cedar (*Thuja occidentalis*), a species that is uncommon in Tennessee, and a population of northern bush-honeysuckle (*Diervilla lonicera*), a shrub classified as threatened in Tennessee.

6. Bear Creek/McNew Hollow Floodplain — The poorly drained bottom along Bear Creek has created a habitat consisting of seeps and swamp forest. Growing in the poorly drained areas are several species of orchids, including the southern rein-orchid (*Plantanthera flava*), a species of special concern for Tennessee.

7. Bull Bluff — This is a precipitous bluff rising more than 322 m above the Clinch River. Growing on this bluff are two rare plants: northern bush-honeysuckle (*Diervilla lonicera*), which is listed as threatened in Tennessee, and bugbane (*Cimicifuga rubifolia*), which is threatened in the state and also under status review for federal listing.

8. McCoy Branch Embayment Barren — This is the site of what is probably the largest population of tall larkspur (*Delphinium exaltatum*) known to occur anywhere. This plant is listed as endangered in Tennessee.

Research activities in these areas are coordinated by NERP with close interaction with TDC. Long-term monitoring studies of a few of the rare plant populations, which have been initiated by NERP, will lead to information useful in determining beneficial management strategies for the plant habitats.

Climatic Change in the Amazon Region (J. G. Saldarriaga, D. C. West, and M. L. Tharp)

Ecologists have long assumed that a very long period of climatic stability prevailed in the Amazon region through most of the Quaternary. However, recent evidence indicates that this region experienced several dry episodes during the Pleistocene and increased precipitation in the Holocene. Extensive scattered deposits of charcoal have been found in the soil in the Upper Rio Negro region of Colombia and Venezuela (in the Amazon basin), which has led us to question the long-term stability of major forests in the region.

The presence of charcoal in forest soils of the Amazon region has been attributed to past human occupation (old village sites) or slash-and-burn agricultural activities. However, the data on settlement and mobility patterns of indigenous populations in prehistoric and colonial times, the environmental stress on human populations during the Holocene, as well as their pattern of land use for agriculture do not corroborate the assumption of an anthropogenic origin for the charcoal found in all types of forests in the Upper Rio Negro of Colombia and Venezuela. Evidence to support the hypothesis of unstable environmental conditions in this area is provided by the amount of charcoal found, its distribution in the soil profile, and the radiocarbon dates.

Several radiocarbon dates for charcoal found in the Upper Rio Negro region correspond to reported dry periods. We found that the dry intervals coincided with the radiocarbon dates for the Upper Rio Negro except for the 1100 to 1300 B.P. wet phase, which coincided with little or no charcoal. These examples suggest that the extreme weather conditions that prevailed in different areas of the Amazon basin during the Holocene reflect climatic fluctuations. In addition, there are

a number of examples of intervals of lower effective precipitation, resulting in lower lake levels during the Holocene in the Andean area, the inland savannas, and the lower Magdalena Valley. These intervals are similar to those in the Amazon basin. The scattered records mentioned above coincide with several climatic episodes that were apparently synchronous around the world either in time or in climatic patterns. Perhaps this indicates synchrony of events in the same region.

The presence of charcoal in the moist, tropical forests of the Upper Rio Negro indicates that this region has been subjected to frequent fires. The fires are the result of lightning occurring during extremely dry periods, slash-and-burn agriculture, or a combination of both climate and human activity. The ^{14}C dates of the charcoal confirm the occurrence of fires in the Upper Rio Negro forests for at least the last 6000 years.

Multiple Nutrient Limitations in Ecological Processes (R. V. O'Neill, D. L. DeAngelis, J. J. Pastor, B. Jackson, and W. M. Post)

Ecological processes are often limited by more than one nutrient; for example, both nitrogen and phosphorus might limit primary production in a particular situation. Therefore, mathematical representation of simultaneous limitations is critical in many modeling and data analysis situations. Eight functions proposed in the literature and three new functions that are candidates for describing multiple limiting factors were evaluated in terms of their ability to fit experimental data and as a basis for developing a general theoretical framework that illustrates commonalities and differences between the functions.

Based on this analysis, four functions for treating multiple nutrient limitations were eliminated as useful representations because they cannot be reasonably calibrated against available data. Two other functions were found to be less useful because they require unreasonable parameter values when parameterized against single nutrient experiments. Two of the functions appear to be adequate representations for treating multiple nutrient limitations. One of these is slightly preferable because of its simplicity and because convergence is stronger in fitting data. For two nutrients limiting productivity, this preferred function, termed the "additive model," is

$$P = P_{\max} N_1 N_2 / (k_2 N_1 + N_1 N_2 + k_1 N_2),$$

where N_1 and N_2 are the abundances of two limiting nutrients and P_{\max} is the maximum value of productivity, P . The parameters k_1 and k_2 are adjusted to calibrate the function to data.

PART II. ENVIRONMENTAL SCIENCES DIVISION PROGRAMS

5. BIOMASS PRODUCTION

J. W. Ranney

D. T. Curtin ¹	D. W. Johnson ²	R. J. Norby ²	J. L. Trimble ²
J. H. Cushman ²	J. W. Johnston ²	E. G. O'Neill ²	A. F. Turhollow ⁵
D. H. Dawson ³	P. A. Layton ²	R. D. Perlack ⁵	C. R. Wenzel ⁶
A. R. Ehrenshaft ⁴	R. J. Luxmoore ²	D. E. Todd ²	L. L. Wright ²
P. L. Henry ²	W. A. McNabb ²		

Introduction

The Environmental Sciences Division (ESD) conducts both program management and supportive research for the U.S. Department of Energy's (DOE) Biofuels and Municipal Waste Technology Division (BMWTD). Under its Biomass Production Program, ESD manages two BMWTD research and development programs on herbaceous and wood energy crop production research: the Short Rotation Woody Crops Program (SRWCP) and the Herbaceous Energy Crops Program (HECP), which comprise 40 subcontracts and interagency agreements. Research conducted at ESD focuses on energy crop nutrient cycling, growth modeling, physiology, programmatic data synthesis, and economic evaluation. Additional activities include DOE-supportive roles in multiyear planning, biofuels technology evaluation, and technical leadership for international activities in biomass energy research.

The main thrust of biomass research in ESD is determining the nitrogen-use efficiency of new energy crops. The approach is one of defining the physical, chemical, and biological actions of organisms in a nitrogen-enriched soil and their effects on nitrogen availability to, and growth of, these new energy crops. Energy crop physiology, photosynthate production and allocation, and root-symbiont interactions are part of this interdisciplinary effort. A pilot stand of green ash (*Fraxinus pennsylvanica*) was planted in March 1986, but little data are available for reporting. This research is partially replicated at Tuskegee University for the purpose of validating our field results and for facilitating ESD research exchange with a historically black university.

Other major efforts include the compilation of a complex wood energy crop data base from which syntheses are now being made, evaluation of the growth capacities of lignocellulosic herbaceous crops under limited management inputs, and comparative economic evaluations of energy crop production strategies.

The subcontracted work in the SRWCP and HECP supports research on the production of new wood and herbaceous energy crops for use as a feedstock for conversion to liquid and gaseous fuels. Improved productivity, cost-effectiveness, environmental acceptability, and feedstock quality are the

¹Tennessee Valley Authority, Norris, Tennessee.

²Terrestrial Ecology Section, ESD.

³Consultant.

⁴Information Resources Organization, ORNL.

⁵Energy Division, ORNL.

⁶Science Applications International Corporation, Oak Ridge, Tennessee.

measures of progress. The research thrusts are in genetics, biotechnology, and physiology; species screening; cultural research; harvesting and handling; biomass composition; and economics.

Growth Modeling of Wood Energy Crops

L. L. Wright and P. A. Layton

In the Short Rotation Woody Crops Program, two different but complementary computerized ecophysiological growth-simulation models are being developed. These models will help us to better understand site, genetic, and silvicultural influences on the growth of wood energy crops and to better direct the genetic improvement of these crops. At the individual tree level, a model for *Populus* is being developed by several subcontractors, based on detailed field and laboratory studies of photosynthesis, respiration, incident solar radiation, and crown architecture and growth habits. At the stand level, modeling efforts, utilizing data generated in the SRWCP, were initiated by ESD and other subcontractors.

The Tree-Level Ecophysiological Model (L. L. Wright)

In the tree-level ecophysiological model, the individual leaf is the principal biological unit (Michael et al. 1985). The model determines the influence of orientation, light interception, temperature, and photosynthate sink demand on the photosynthetic capacity of individual leaves. The performance of individual leaves is then integrated to obtain an estimate of the hourly and daily photosynthate production, the distribution of the accumulated photosynthates throughout the plant, and the conversion of photosynthates into dimensional growth. Once the site characteristics and microclimatic conditions are defined for a particular environment, the computer model requires relatively few input variables to describe the morphological and phenological characteristics of a clone. Through an iterative process on a personal computer, the model can provide an estimate of the biomass production, height, diameter, weight, and volume of a clone.

At present the model is limited to simulating the growth of a 1-year-old tree with <100 leaves. However, considering the 3- to 8-year rotation in wood energy crops, the correlations between harvestable trees and 1-year-old seedlings may be large, and, therefore, the early selection provided by this model could be extremely relevant and useful for breeders. The model provides a graphic display of the leaves on the tree, which allows the breeder to visualize the effects of changes in leaf orientation on solar radiation interception (Fig. 5.1). The model can test hypotheses regarding how modifications in architecture and carbon allocation patterns affect first-year production rates in a given environment as well as predict the performance of a given tree architecture in different environments. Thus, tree ideotypes can be designed for different environmental conditions. This tree-level simulation model is expected to be a very useful tool to geneticists for identifying juvenile traits in *Populus* that strongly influence yield.

The Stand-Level Ecophysiological Model (L. L. Wright)

The premise of the stand-level ecophysiological model is that the production of biomass (measured by dry weight) in plant communities is proportional to the radiant energy absorbed by the canopy. This model differs from the tree-level model in assuming that the stand canopy can be adequately described in a simplistic manner. The basic equation of the model for a given unit of time relates the net dry matter production to a function of the amount of shortwave light absorbed and

ORNL-DWG 86-16620

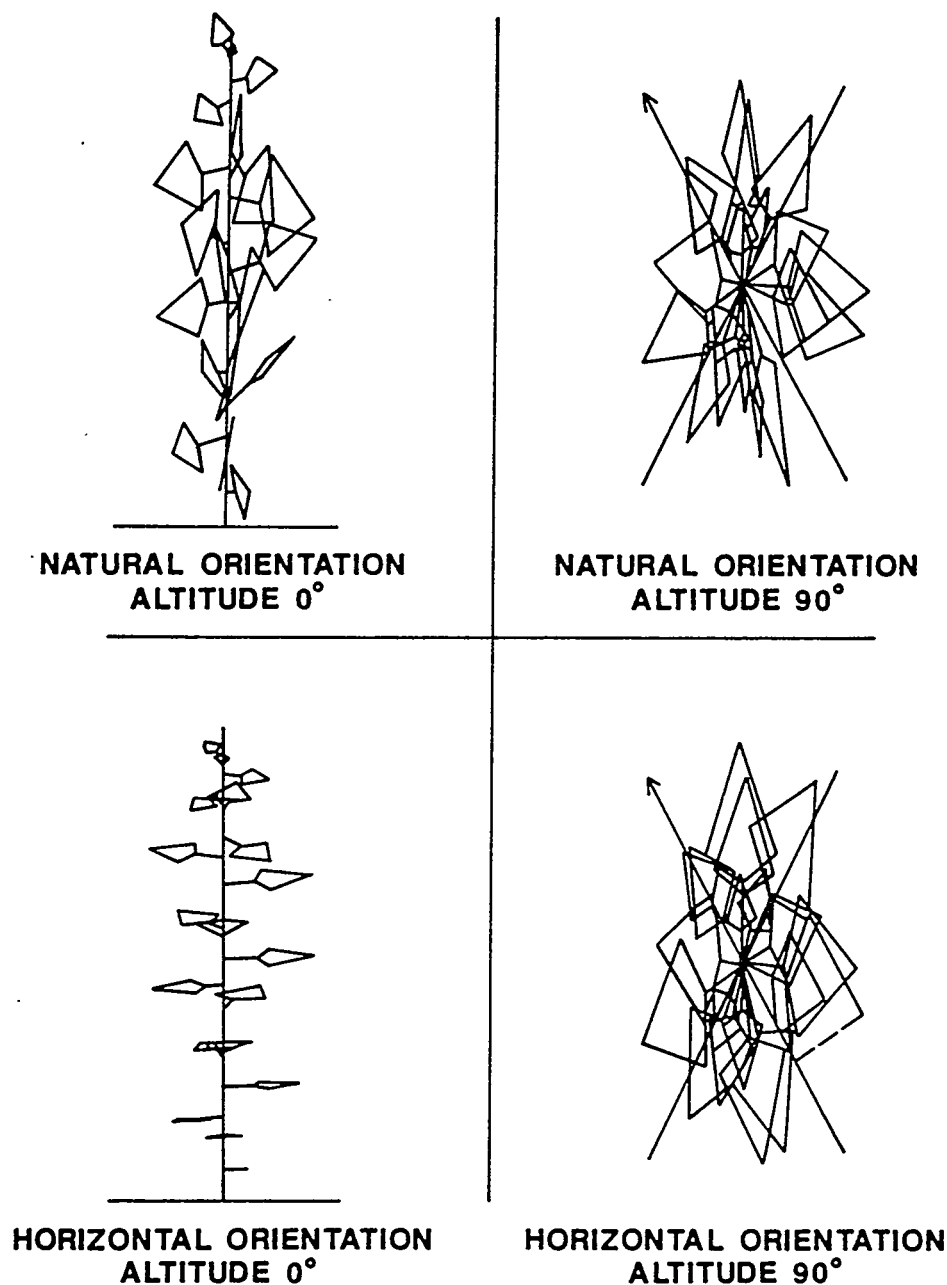


Fig. 5.1. Computer output generated by tree-level ecophysiological model, showing leaf orientation from side and top. Altitude refers to the relationship of the sun to the trees, with altitude 90° being directly overhead. Source: E. A. Hansen, B. Haassig, J. G. Isebrands, and D. Riemenschneider. 1986. Increasing yields of *Populus* energy plantations. Unpublished annual report submitted to the U.S. Department of Energy's Short Rotation Woody Crops Program. U.S. Department of Agriculture, North Central Forest Experiment Station, Rhinelander, Wisconsin.

the efficiency of a crop in converting that light to biomass. Light absorption is assumed to be a function of leaf area development that can be estimated using information on maximum leaf area, date of leaf emergence, and end of leaf fall.

Subcontractor data on the first-year growth of *Populus* hybrid NE 388 indicate that the energy-conversion efficiency of 1-year-old crops is 0.00016 kg/MJ and that of 2-year-old and older crops is 0.0007 kg/MJ under the best cultural conditions (Fig. 5.2). A limitation of the model is that energy allocation to roots is not accounted for, a possible reason for the lower apparent conversion efficiency of the plants in the first year.

A computer simulation based on the basic equation and parameterized by field results demonstrates that photosynthate partitioning to leaves must be high early in the growing season in order to produce the leaf masses observed in *Populus* stands. This agrees with carbon allocation patterns determined in ^{14}C tracer studies (Isebrands and Nelson 1983). Although, in theory, a stand-level model such as this could predict the yield obtainable from any area with input of actual radiation data for that area, the model needs to be tested with other species and factors (e.g., fertility levels, density) affecting the parameter values investigated before it can be used with any confidence in predicting obtainable yields in a given area. However, the model can be used now to perform sensitivity analysis on traits such as leaf area dynamics that are under genetic control to help geneticists establish the ideal traits for maximizing productivity.

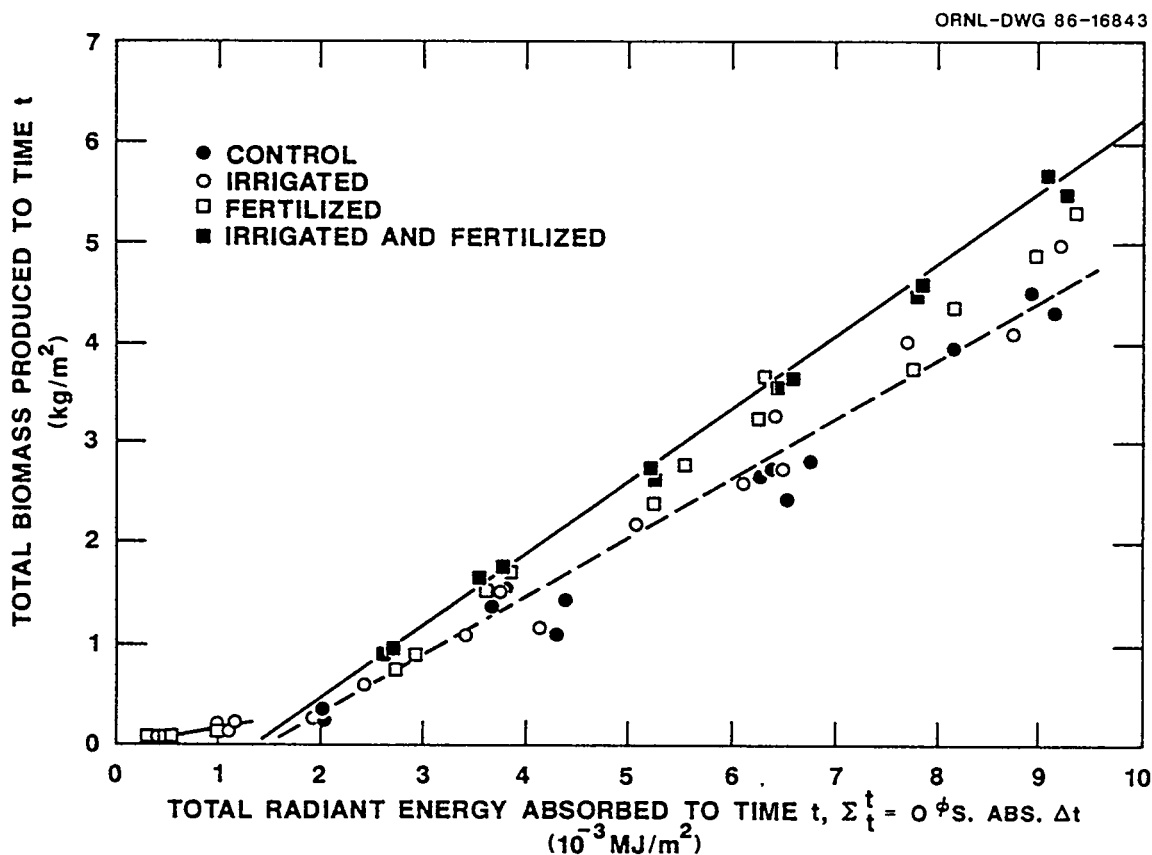


Fig. 5.2. Total biomass produced to time t as a function of total radiant energy absorbed to time t . Solid line indicates maximum slope of the data.

Integration of Tree- and Stand-Level Models (L. L. Wright and P. A. Layton)

An understanding of stand competition processes is needed in selecting species and clones that can tolerate competition and in optimizing densities and rotation lengths in order to obtain high yields in both seedling and coppice stands. Competition is therefore seen as the integrating phenomenon for the two models.

Based on preliminary analysis of SRWCP information (including five tree species), competition-induced mortality appears to be a linear function of density. This can be described by a consistent relationship between tree size and density or spacing of trees (or self-thinning line), which, for many plant species, has a slope of -1.5 when weight is the dependent variable. The slope determined by analysis of several short-rotation intensive culture (SRIC) stands at densities from 1000 to 100,000 trees per hectare was somewhat less (-1.25) than would normally be expected, and in some density ranges the data did not conform well. Thus, the relationship is not sufficiently substantiated by the available data to use it for making management decisions. However, the analysis is informative because it indicates that a solid predictive relationship could be established if a single genotype and cultural treatment were applied to a wide range of densities. Such a study is currently being conducted to test this. The analysis also shows that different hardwood species (sharing a trait of intolerance to competition) have relatively similar size-density relationships. Similar evaluations need to be made with wood energy species that are more tolerant of competition and with improved genotypes of intolerant species. The expectation is that improved competition tolerance and/or improved growth characteristics will either increase the size of trees before stands reach a self-thinning phase or bring on earlier initiation of self-thinning.

Translating the thinning phenomenon to its effects on individual leaf growth, distribution, and photosynthate partitioning will soon be possible, after a few key trials on monitoring individual tree leaves. Modelers will then be able to alter the models of specific tree traits at will to determine their influences on stand-level productivity. Geneticists will then test these results.

Improvement of Herbaceous Lignocellulosic Energy Crops

J. W. Johnston

Lignocellulosic crops, which include the traditional forage and hay crops, are the primary focus of HECF research activities. Field research in lignocellulosic crop production was initiated at five institutions during FY 1985 (Fig. 5.3). The research focuses on establishing and screening promising lignocellulosic crop species for the production of energy feedstocks on lands that are marginal for row cropping in the Southeast and the Midwest-Lake States (Cushman, Turhollow, and Johnston 1986). These regions were chosen for study because of the abundance of marginal cropland potentially available for energy crop production and because climatic factors, such as rainfall and growing season, are adequate to sustain high levels of productivity. The research program includes a screening component in which several promising species are grown under a variety of conditions at sites that are marginal for conventional row crop production. Soil suitability factors that contribute to characterization of a site as marginal include erosion potential, chemical and physical constraints on rooting, and excessive wetness. The species being screened are primarily perennial grasses and legumes, although several annual grasses and one annual *Brassica* species are also being tested. Biomass yields are expressed as mass per unit of land area, and chemical yields are expressed as percent of lignin, cellulose, hemicellulose, nonstructural carbohydrates, protein, and ash.

ORNL-DWG 86-16844

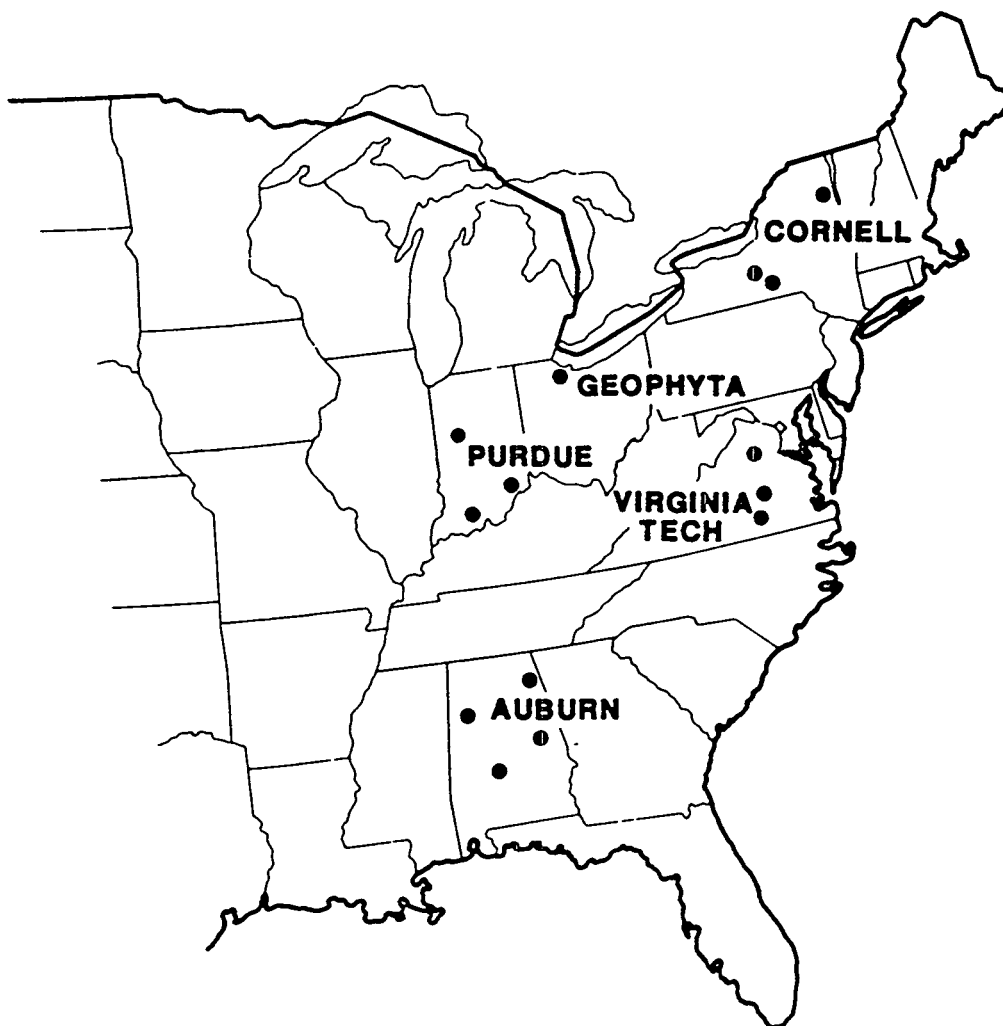


Fig. 5.3. Locations of the field sites for the Herbaceous Energy Crops Program's lignocellulosic crop screening studies in the Midwest-Lake States (Cornell University, Geophyta, and Purdue University) and in the Southeast (Auburn University and Virginia Polytechnic Institute and State University).

The crop establishment phase of the lignocellulosic crop screening effort has been completed. There were no difficulties in establishing annual species because consistently wet spring weather, which is most often the limiting factor in establishment of annual crops, was not a problem.

The perennial crops exhibited a broad range of establishment success. Soil characteristics related to wetness and texture and meteorological factors, such as drought and freeze-thaw cycles that favored frost heaving, were the factors that limited establishment of perennial crops. Frost heaving was the most important factor on chronically wet, poorly drained sites. In addition, the high proportion of clay, which is characteristic of chronically wet soils, can lead to crust formation in cultivated soils following heavy rains. Crusting inhibits development of seedlings whose growth is

not rapid enough for emergence during the 2 or 3 d following rain. On sites without wetness problems, the greatest deterrents to establishment were soil conditions that caused sensitivity to drought. The fall and spring droughts of 1985 and 1986 in the southeastern United States limited the establishment of crop plantings in Alabama and Virginia, respectively. Fall plantings that were not acclimatized prior to the unusually abrupt transition to winter conditions in December of 1985 in the Southeast experienced a high incidence of winter kill.

This research has demonstrated that seedling establishment is more risky on marginal croplands than on good cropland. Fall-planted crops must be planted earlier on marginal land in order to attain adequate growth to avoid winter kill and to form a sufficient root mat to avoid damage from frost heaving. In addition, no-till planting methods are preferable to traditional cultivation in many cases for two reasons: (1) conservation of soil moisture in drought-prone soils and (2) the avoidance of crust formation in soils with a high proportion of clay.

Of the annual crops, sweet sorghum exhibited the greatest productivity, with dry matter yields in excess of 25 dry Mg/ha in Alabama and Indiana. Pearl millet and sorghum \times sudangrass were next highest in productivity, with dry matter yields of 16.5 Mg/ha and from 12.9 to 17.2 Mg/ha, respectively. The responses of these crops to nitrogen fertilization were dramatic (Fig. 5.4), with

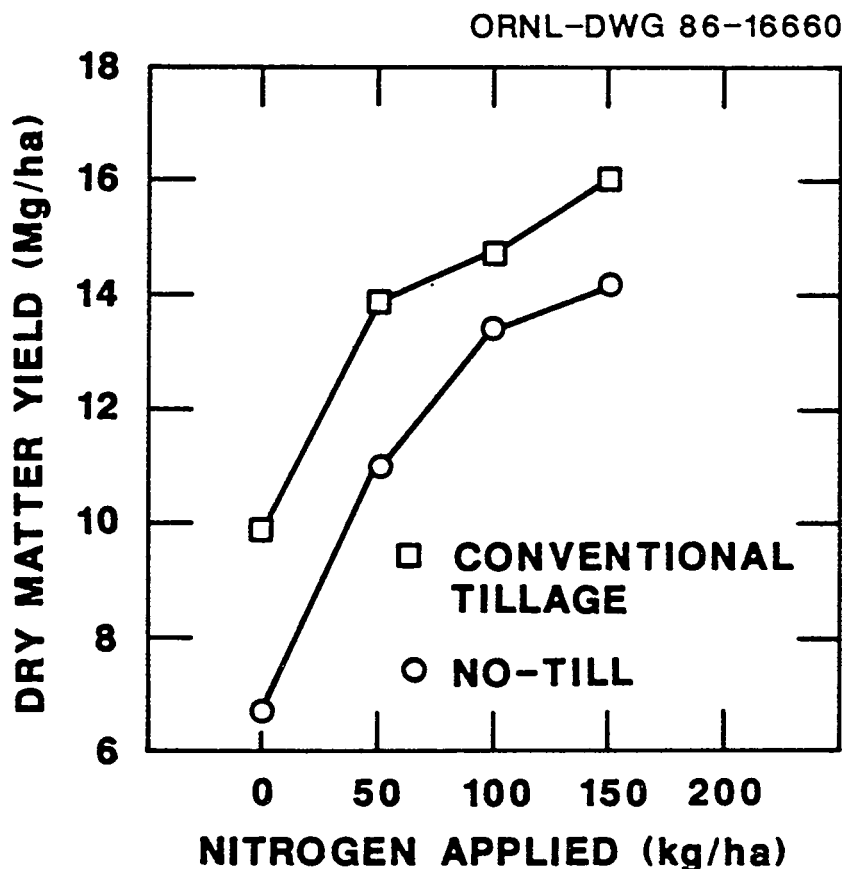


Fig. 5.4. Mean response of *Sorghum bicolor* \times *S. sudanense* to nitrogen fertilization and tillage treatment at four sites in Indiana (1986).

yields in no-till plots doubling with the addition of 150 kg N/ha. These yields are very encouraging, considering the marginal soils in most of the research locations and the current lack of information identifying optimum management practices for energy crop production. In addition, these annual crops will be grown primarily as the summer component of a double-crop system. Rye grown on marginal soils averaged 4.3 Mg/ha in Indiana and 4.7 Mg/ha in Alabama as the winter component of a double-crop system with sweet sorghum. In Alabama, a combination of rye and sweet clover produced up to 9.5 Mg/ha as a winter component of the 1985 sorghum double-crop system. It appears likely that yields of 40 Mg/ha will be common in years with adequate rainfall for double-cropped winter and summer annuals in the Midwest and Southeast once the optimal species combinations and crop management techniques are identified.

Perennial grass and legume crops seldom exhibit maximum annual productivity in their establishment year. Therefore, the yields from the 1985 growing season must be interpreted with that fact in mind. Nevertheless, there were excellent yields from some perennial crops in their establishment year. Johnsongrass produced 10.8 Mg/ha, and switchgrass and *Sericea lespedeza* produced >5 Mg/ha at some Alabama sites. Significantly greater yields are anticipated in subsequent years. The perennial grasses responded positively to fertilizer additions, although the increases in yield were not as great as those for annual grasses. Switchgrass yields were increased 44% with the addition of 200 kg N/ha. The cost-effectiveness of alternative management practices, such as conventional tilling vs no-till cultivation, double cropping, and fertilization, will be determined in subsequent years as more information from the screening efforts becomes available.

Improvement of Oilseed Energy Crops

A. F. Turhollow

The secondary focus of HECP research is on the production of vegetable oils as diesel fuel substitutes. The emphasis of this research is on development of winter rapeseed (*Brassica napus*) as a winter annual in the Southeast. Although other crops produce oils that can be used as fuel in diesel engines, their greatest value is primarily as a food crop. The characteristic of winter rapeseed that sets it apart from the other oilseed crops is its ability to grow as a winter annual in the Southeast, where it can be planted in the fall, after the harvesting of corn, and harvested in the spring in time to plant soybeans, sorghum, or other summer crops. Therefore, winter rapeseed can be grown in an otherwise fallow period in a crop-rotation system and provide a diesel fuel substitute without competing with food crops for land. An additional benefit is the reduction of soil erosion provided by a winter ground cover.

Oilseed research funded by the HECP is primarily concerned with developing a variety of winter rapeseed having a combination of traits that favor its production for a diesel fuel substitute as the winter crop of a double-crop system. Some specific desirable traits are (1) high yields, (2) shatter-resistant seeds, (3) low glucosinolate content in the meal, (4) resistance to the herbicide atrazine, and (5) regionally appropriate photosensitivity and vernalization requirements.

High yield is the most important criterion in determining the economic viability of winter rapeseed as an energy crop. Increased plant growth results in more seed available for harvest. High shatter resistance of the seeds and improved harvesting methods will increase the proportion of seeds actually harvested. Reduction of glucosinolates, a family of toxic compounds found in most rapeseeds and mustards (*Raphanus* spp.), will allow the use of rapeseed meal as an edible protein supplement for livestock, thus increasing the total value of the crop. Atrazine resistance is required

so that naturally occurring *Raphanus* spp., which carry undesirable traits (e.g., high glucosinolate content or polyunsaturated oils) that are potentially transferable to the improved seed stocks through cross-pollination, can be eliminated.

The economic viability of winter rapeseed as an energy crop depends to a large extent upon its use as the winter component of a double-crop system. Appropriate photoperiod sensitivity and vernalization characteristics are being incorporated into improved seed lines so that plants mature early enough to be followed by soybeans, sorghum or peanuts, and yet avoid winter kill problems that will occur if the plants break dormancy too early.

In addition to the selective breeding activities summarized above, oil-extraction efficiency experiments are being conducted. The extraction efficiency of rapeseed oil is being examined, using carbon dioxide and other solvents, and procedures that minimize the extraction of gums and other undesirable chemical fractions are being developed.

References

- Cushman, J. H., A. F. Turhollow, and J. W. Johnston. 1986. Herbaceous Energy Crops Program: Annual progress report for FY 1985. ORNL-6263. Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Drew, T. J., and J. W. Flewelling. 1977. Some recent Japanese theories of yield-density relationships and their application to Monterey pine plantations. *For. Sci.* 23:517-534.
- Drew, T. J., and J. W. Flewelling. 1979. Stand density managements: An alternative approach and its application to Douglas-fir plantations. *For. Sci.* 25:518-532.
- Isebrands, J. G., and N. D. Nelson. 1983. Distribution of [^{14}C]-labeled photosynthates within intensively cultured *Populus* clones during the establishment year. *Physiol. Plant.* 59:9-18.
- Michael, D., M. Rauscher, J. Isebrands, T. Crow, R. Dickson, and D. Dickmann. 1985. An eco-physiological growth model of poplar, I. Leaf orientation, light interception, and photosynthate production (abstract). pp. 82-83. IN Program and Presentation Summaries of International Symposium on Whole-Plant Physiology, Knoxville, Tennessee, October 6-11, 1985. CONF-851050-ABSTS. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

6. CARBON DIOXIDE RESEARCH PROGRAM

C. C. Coutant

M. D. Burtis	A. W. King ⁴	E. G. O'Neill ¹
V. H. Dale ¹	R. J. Luxmoore ¹	T.-H. Peng ⁵
D. L. DeAngelis ²	L. K. Mann ¹	W. M. Post ¹
R. H. Gardner ²	R. J. Norby ¹	J. S. Sanford
H. I. Jager ³		

Introduction

The Oak Ridge National Laboratory (ORNL) Carbon Dioxide Research Program was restructured in 1986 to continue administration of the U.S. Department of Energy's (DOE) Global Carbon Cycle Program and to oversee the Laboratory's research for the DOE Carbon Dioxide Research Division on the carbon cycle and the biological effects of increased atmospheric carbon dioxide (CO₂). The DOE Global Carbon Cycle Program has focused on understanding and modeling the dynamic balance among global CO₂ sources and sinks, which determines the rate of increase in the atmospheric CO₂ concentration. The observed increase in the CO₂ content of the atmosphere is only about half the estimated release from fossil fuel consumption because of interactions between the atmosphere and other global carbon reservoirs. These interactions must be understood to provide a basis for developing models that will project future changes in the concentration of atmospheric CO₂ as fossil fuel use continues. The carbon reservoirs known to be important in the response to anthropogenic CO₂ are the atmosphere, the ocean, and the terrestrial biosphere (including soils). Work on the effects of increased CO₂ centers on the potential for enhanced fixation of carbon by plants.

Understanding the fate and effects of CO₂ requires very different approaches than does the solution of more traditional pollution control or experimental scientific problems. It involves deciphering the carbon cycle of the whole globe. For several centuries, industrialization and changes in the landscape have significantly disturbed the natural biogeochemical cycles of carbon and the nutrients such as nitrogen and phosphorus that regulate biological fixation of carbon. Evaluating what happened in the past and what may happen in the future requires an understanding of conditions that existed in the past when CO₂ levels in the atmosphere fluctuated with changes in the terrestrial landscape (e.g., the ice age) and in ocean circulation patterns. Development of a knowledge base for the carbon cycle is a long-term research effort requiring that (1) a variety of recorded historical and contemporary changes in the concentration of atmospheric CO₂ be understood; (2) the interactions of fossil fuel emissions, the biosphere, and the ocean with the atmosphere, expressed as fluxes, be quantified; and (3) models that accurately represent the major fluxes over time be developed for interpreting the past and predicting the future.

The Global Carbon Cycle Program is responsible for monitoring the progress of DOE-supported research, identifying needs, and recommending methods for filling those needs. The

¹Terrestrial Ecology Section, ESD.

²Aquatic Ecology Section, ESD.

³Science Applications International Corporation, Knoxville, Tennessee.

⁴Graduate student, University of Tennessee, Knoxville.

⁵Earth Sciences Section, ESD.

ORNL staff administers subcontracted research efforts at universities and major research institutions for the development of carbon cycle models and the acquisition of necessary supporting data. A major activity this past year involved reevaluation of program goals and objectives in light of publication of a report for the DOE state-of-the-art series on global carbon cycle research (Trabalka 1985), with contributions from an international team of authors and reviewers.

The results from both the state-of-the-art review and ongoing studies reinforce the need for a balanced research perspective and long-term studies to resolve existing carbon cycle questions and to begin to incorporate potential feedbacks to atmospheric CO₂ from anticipated climate changes. Predictions of future atmospheric CO₂ concentrations under increased loading from fossil fuel emissions and climate changes must be based on carbon cycle models that accurately depict quantitative rates of carbon exchange among and within the major global reservoirs. As a first approximation in the validation of models, it should be possible to compute a balanced global carbon budget for the contemporary period, but to date this has not been achievable. A reduction in the current discrepancy between alternative views of the global cycle by, for example, oceanographers and terrestrial ecologists, may not be possible without a more basic understanding of fundamental patterns and processes, the principal obstacle to which is lack of relevant field data (e.g., the natural controls on terrestrial storage, the role of subfossil pools, and especially the relationship of ocean CO₂ uptake to circulation patterns and climate). Symptomatic of the scale of recent ignorance is the discovery in the past year that the North Pacific Ocean, assumed in most carbon flux computations to be a large sink for atmospheric CO₂, is actually a major global source. This abrupt reversal came about because of DOE-sponsored sampling during winter (a season heretofore ignored) when the major degassing events occur.

Other areas also defy adequate representation in predictive models for future CO₂ levels. Subfossil carbon storage pools in soils, sediments, and peat and the land-ocean interface have been largely ignored up to now, but appear to be much more significant than formerly thought. Land-use changes, principally deforestation, contributed to the rise in atmospheric CO₂ levels, but current mathematical models of the global carbon cycle cannot accommodate contemporary biospheric releases in addition to fossil fuel releases. Current models produce estimates of past atmospheric CO₂ levels that are inconsistent with the historical record of increases in atmospheric CO₂. If we are unable to correctly represent what is happening today, even on a gross scale, it is illogical to place much faith in our estimates of future CO₂ concentrations.

Although the initial focus of the ORNL contributions to the DOE Global Carbon Cycle Program was on the terrestrial component of the carbon cycle, there has been expansion of support for oceanic research, particularly field studies (e.g., collaboration with French scientists on Indian Ocean studies) and three-dimensional modeling. The continued development of the ORNL program has involved increased coordination among extramural subcontractors to meet program goals.

Extramural Research

Development of a Three-Dimensional Model of the Natural Carbon Cycle in the Oceans and Its Perturbation by Anthropogenic CO₂ (R. B. Bacastow¹)

A model of the carbon cycle in the oceans, based on an ocean general circulation model, has been developed in collaboration with E. Maier-Reimer of the Max Planck Institute for Meteorology

¹Scripps Institute of Oceanography, La Jolla, California.

in Hamburg, Federal Republic of Germany. The ocean general circulation model employs filtered equations and runs about an order of magnitude faster than primitive equation models. The carbon cycle model represents the oceans by 27,218 mixed reservoirs (boxes) arranged in 10 levels. The depths of the boxes vary from layer to layer so as to give more resolution through the thermocline. The lowest box in each column extends to the local ocean bottom. Near the equator the horizontal resolution is ~ 500 km. The general circulation model provides monthly values of the distribution of currents, or the current field, but the carbon cycle model at present uses yearly averaged values. Transport and mixing are provided by the current field of the circulation model, explicit horizontal diffusivity, a convective adjustment, and the numerical diffusivity caused by the box size. An atmospheric box exchanges CO_2 , $^{14}\text{CO}_2$, and $^{13}\text{CO}_2$ with the surface ocean boxes. Radiocarbon and the stable isotope ^{13}C are distributed among the atmosphere, ocean, and ocean biota according to known factors. The ocean biota are assumed to affect ocean chemistry by sinking downward after death, with subsequent remineralization and dissolution of soft tissue and hard tissue [calcium carbonate (CaCO_3)] taking place in boxes directly beneath where they are produced. The downward flux of soft tissue from the surface box is modeled as dependent on a latitudinal factor and the phosphate concentration. The downward flux of hard tissue is taken to be a fraction of surface production. Remineralization of the soft tissue flux is prescribed by selecting values for the fraction of the downward flux of soft tissue that is returned to solution in the K^{th} -level box. These values have been set in such a way that the exponential penetration depth below the surface box is 700 m. Dissolution of hard tissue is similarly prescribed. Surface boxes are assumed to be 3% supersaturated with oxygen, and remineralization of soft tissue is accompanied by a reduction in the oxygen concentration. If there is not sufficient oxygen, remineralization is suppressed.

A comparison of model results with observational data shows many similarities. The ^{14}C age of the deep water is now almost correct. The main discrepancies between model distributions and observed distributions seem to be related to the thermohaline circulation, which is probably still not quite right. Two versions of the circulation-based model take up fossil fuel CO_2 less readily than extant box-diffusion models.

The Effect of Pressure on Aragonite Dissolution Rates in Seawater (J. G. Acker,¹ R. H. Byrne,¹ S. Ben-Yaakov,² R. A. Feely,³ and P. R. Betzer³)

The oceans play an important role in the absorption and neutralization of atmospheric CO_2 . One of the primary mechanisms by which neutralization takes place is the dissolution of calcium carbonate (CaCO_3). Sea-floor carbonate sediments constitute a reservoir that is sufficient to neutralize the anticipated increase in atmospheric CO_2 due to anthropogenic input, although the rate of neutralization will determine whether the peak atmospheric CO_2 content reaches values that are 300% greater or only 40% greater than preindustrial values. Since most of the carbonate sediments susceptible to dissolution are found at great depths in the ocean, it is important to accurately assess the kinetics of the CaCO_3 dissolution process for the global setting in which much of the dissolution will take place.

¹University of South Florida, Tampa.

²Ben Gurion University, Israel.

³Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, Seattle, Washington.

A major area of uncertainty in modeling the neutralization of atmospheric CO_2 by the oceans is the functional dependence of the CaCO_3 dissolution rate on the degree of seawater undersaturation.

The dependence of carbonate saturation on pressure causes the various equations employed to differ substantially in their predictions of CaCO_3 dissolution in the oceans. Saturation concentration increases by a factor of ~ 2 between the surface ocean and 6000-m depths. Consequently, the dissolution rate at a depth of 6000 m could be ~ 4 times greater than a corresponding rate measured at atmospheric pressure.

We performed CaCO_3 dissolution experiments under low-temperature, high-pressure conditions, which simulate the deep-ocean environment. Our experiments made use of freshly collected pteropod shells, which are composed of aragonite, and samples of natural seawater from various depths between 100 and 5000 m. The pteropod shells were obtained from free-floating sediment traps, and the seawater samples were obtained by hydrocasts. Each of our shipboard dissolution experiments was performed on pteropod shells and seawater containing phenol red ($8 \times 10^{-6} M$) placed in a variable-path-length spectrophotometric cell that could be pressurized. Our results showed that aragonite dissolution in seawater at variable pressure could be well described quantitatively.

Assessment of Seasonal and Geographic Variability in CO_2 Sinks and Sources in the Ocean (T. Takahashi¹)

An observational program on the seasonal and geographic variability in the CO_2 sinks and sources in the ocean is critical to our understanding of the role of the ocean in the global CO_2 cycle. In the past 2 years, we have investigated the seasonal variability in the carbon and nutrient chemistry of the North Pacific surface water. The measurements made during six trans-Pacific crossings, between November 1984 and February 1986, include the partial pressure of CO_2 ($p\text{CO}_2$) in surface water and in air, the concentrations of total CO_2 and phosphate dissolved in surface water, temperature, and salinity.

The North Pacific Ocean north of about 40°N is a net source for atmospheric CO_2 and exhibits a large seasonal variation in carbon chemistry. During the winter, the surface water has high concentrations of total CO_2 and phosphate and also exhibits high $p\text{CO}_2$ values (and is therefore a strong CO_2 source), although the water is colder. The situation is reversed in the summer: the water has much lower $p\text{CO}_2$ values when it is warmer and becomes a weak CO_2 sink. The high winter values are attributed to upwelling of subsurface water rich in CO_2 and nutrients, whereas the low summer values are due mainly to the photosynthetic utilization of CO_2 . Since this high-latitude oceanic CO_2 source is attributed to the cooling of surface water and the resulting deep convective mixing in the winter, its intensity should be reduced by CO_2 -induced climatic warming. Under such a condition, the high-latitude oceans would be expected to provide a negative feedback in the CO_2 -ocean-climate system.

The uptake flux of CO_2 by the global oceans has been estimated, using the available $p\text{CO}_2$ data and the gas transfer coefficient, which is taken to be proportional to wind speed. It was found that the net oceanic uptake flux is ~ 2.6 Gt of carbon per year, which corresponds to $\sim 50\%$ of the

¹Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York.

current industrial CO₂ emission rate. Among the oceanic CO₂ sources, the equatorial belt and the high-latitude North Pacific represent, respectively, 65 and 15% of the total source flux. The sub-Antarctic and Antarctic waters and the high-latitude North Atlantic are the major oceanic CO₂ sinks, each representing 40, 30, and 13% of the total uptake flux.

The Role of Tropical Forests in the Global Carbon Cycle (S. Brown¹ and A. E. Lugo²)

This research project is designed to fill important gaps in the data base on tropical forests and thus improve (1) modeling efforts related to the role of tropical forests in the global carbon cycle and (2) historical reconstructions of tropical land use and carbon stocks. The project seeks to estimate the rates of decomposition of woody debris in disturbed tropical forests and to determine expansion factors for converting tropical forest volume data to carbon standing stocks.

In 1986 samples of woody debris were collected from four life zones (tropical dry, moist, moist transition to dry, and rain forest) in Dominica and Venezuela. Samples of decomposed and fresh wood were obtained for 20 species of trees, ranging in age from 1 to 20 years, from 5 life zones. The rates of decomposition for 11 tree species were determined based on 4 diameter size classes (spanning 10 to >40 cm in size). We obtained an extensive data set that gives detailed information on individual trees in 25 0.25-ha plots in late secondary and primary forests in 5 life zones in Venezuela: tropical very dry, dry, moist, lower montane moist, and wet forest. To convert forest stand data to carbon estimates, we compiled an extensive list of specific gravities for tropical American trees and developed a new set of biomass regression equations. Thirteen equations calculate total aboveground biomass based on a combination of tree height, diameter at breast height, and specific gravity for a single life zone or combinations of life zones.

The average decomposition coefficients of woody debris, grouped across five life zones and eight species, are 0.063/year for wood <30 cm in diameter (branches) and 0.033/year for wood >30 cm (boles). Expressed on the basis of the time required for 99% of the wood to decompose, these coefficients translate into about 70 to 80 years for small size classes and 100 to 200 years for large size classes. For woody debris in pastures in a wet forest life zone, these times are reduced by a factor of ~3, regardless of species and diameter. These decomposition rates are almost a magnitude lower than those reported in the literature for tropical forests. They have important implications for terrestrial carbon models of land-use changes in the tropics, which produce significant quantities of woody debris (e.g., logging), because they suggest that carbon release from this component may be slower than previously modeled.

Comparison of Pre- and Post-Atomic-Bomb Radiocarbon in Soils (J. W. C. White³ and W. S. Broecker³)

The soil carbon cycle is a potentially important, but as yet poorly quantified, component of the global carbon budget. Constraints on the time scales of carbon cycling between the atmosphere, biosphere, and soil reservoirs are provided by comparing the distribution of ¹⁴C in pre- and post-atomic-bomb soils and soil organic matter fractions. Soil carbon is a complex mixture of compounds

¹University of Illinois, Urbana.

²Center for Energy and Environment Research, Puerto Rico.

³Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York.

which accumulate and decay at different rates. In order to assess what portion of the soil reservoir can affect atmospheric CO_2 on short time scales most relevant to present concerns over anthropogenic changes, it is necessary to separate those portions which are old and stable from those which are young and labile.

Our work of the past 2 years has resulted in the development of a method which consistently separates soil organic matter into fractions with different mean residence times. In all, four different fractionation schemes have been tested using five sets of pre- and post-atomic-bomb soil pairs. We have settled on a combination of fractionation by density and acid hydrolysis as the best procedure. This fractionation scheme has been applied to study the carbon cycling in soils from a well-documented site in the San Dimas Experimental Forest in California. A preliminary model of soil carbon dynamics has been developed based on the most extensive set of soil samples analyzed to date.

The Role of CaCO_3 Compensation in the Glacial-to-Interglacial Change in Atmospheric CO_2 Content (W. S. Broecker¹ and T.-H. Peng)

The only viable explanations put forth to date for the glacial-to-interglacial change in atmospheric CO_2 content suggested by the measurements of the CO_2 content of gas extracted from ice cores involve changes in the ocean's nutrient cycles. Any nutrient change capable of producing the quantitative changes in atmospheric CO_2 pressure suggested by the ice core results would also produce significant changes in the deep ocean's CO_3^{2-} content. These CO_3^{2-} changes are compensated on the time scale of a few thousand years by reductions or increases in the amount of CaCO_3 accumulating in deep sea sediments. Modeling of ocean-atmosphere interactions show that this compensation process has two important consequences. First, it roughly doubles the magnitude of the CO_2 change per unit of nutrient forcing. Second, it causes a delay in the change in atmospheric CO_2 content. While the first of these consequences is a boon to those seeking to explain the CO_2 change, the second may prove to be a curse. The ice core CO_2 record shows no evidence of a significant lag between the CO_2 response and the polar warming. It is important that we improve our knowledge of the magnitude and timing of the CaCO_3 preservation event, which marked the close of glacial time, and of the dissolution event, which marks its onset.

The Role of Ocean CO_2 Sources and Sinks in the Southern Hemisphere: Data Analysis and Modeling (M. A. Palecki² and R. G. Barry²)

What is the role of the Southern Hemisphere oceans in seasonal and interannual CO_2 variations, and how would the CO_2 uptake rate change in a warmer ocean? Given that CO_2 doubling in air will raise global temperatures $\sim 3\text{--}4$ K and eventually raise the temperature of the ocean mixed layer, this might slow the CO_2 uptake by the global ocean, leading to a positive feedback effect with further atmospheric warming.

The rates of CO_2 change in the air at 13 stations from 20°N to 90°S for periods of 6 to 27 years were cross-correlated with atmospheric and ocean variables—land surface air temperature, sea surface temperature (SST), sea surface exchange velocity, and the extent of sea ice around Antarctica—to examine the relationships on seasonal-to-interannual time scales. The results con-

¹Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York.

²University of Colorado, Boulder.

firm the well-established relationship between the Southern Oscillation Index and CO₂ measurements, but leave open the cause. High-latitude anomalies of temperature and wind velocity have been proposed as causes, but the data show only weak support. Large positive correlations between CO₂ change and SST at 20-40°S are restricted to the central Indian Ocean. Correlations with exchange velocities in the southern temperate zone are stronger, but involve a 5-month lag. Sea ice extent shows no effect, except perhaps locally at the antarctic coast. The eastern equatorial Pacific Ocean SST is well correlated with CO₂ change. The CO₂ is driven from the water as temperatures rise, but changes in marine biota off Peru may be more important than temperature.

A model which successfully simulates seasonal CO₂ cycles was perturbed by varying zonal SST or winds. Unrealistically large variations are needed to obtain CO₂ anomalies that compare in magnitude (but not timing) with those observed. Oceanic changes affecting CO₂ sources and sinks explain $\leq 33\%$ of the observed weak CO₂ anomalies related to El Nino-Southern Oscillation events.

There was unexpected evidence of terrestrial biosphere effects: land surface air temperatures affecting tropical rain forest areas of South Asia, South America, and central Africa showed strong positive correlations with CO₂ change with short lag times. This implies that increased plant respiration and litter decay in response to higher temperatures outweigh carbon fixation by vegetation. These results point to the terrestrial biosphere as a major factor controlling the observed interannual CO₂ anomalies. Positive feedback to CO₂ levels in the atmosphere could be important over the decades needed to reduce litter stockpiles and equilibrate production and decay in a warmer climate.

Increase of Total CO₂ in the World Oceans (C.-T. A. Chen¹)

This project collects carbonate data from the oceans to develop an understanding of the seasonal and interannual variations in the oceanic carbon cycle and the feedback mechanisms in the regions where subsurface water is formed in order to quantify oceanic penetration of excess CO₂. The current investigation of the carbonate chemistry of the three major oceans and the Bering, Red, and Weddell seas has achieved the following.

Evaluations of seasonal, cross-frontal and cross-ice-edge variations in carbonate chemistry in the Bering and Weddell seas, in the Indian Ocean, and in the northern North Atlantic Ocean showed that conservative mixing dominates the distribution of chemicals. The Weddell Sea pack ice was found to contain high concentrations of calcium and high alkalinity. The Weddell Sea ice blocks the air-sea exchange of gases, whereas the Bering Sea ice does not. The winter values for oxygen, carbonates, and nutrients deviate significantly from the summer values when data from the same region are compared. The difference is much smaller, however, when data at the same temperature are compared.

The penetration depth of the excess anthropogenic CO₂ in the Atlantic and Pacific oceans was estimated, with excellent qualitative and quantitative correlations being found between the excess CO₂ results and transient tracer data (tritium, ¹⁴C, Freons). The calculations show that penetration depth is strongly related to circulation. The shallowest penetration is <300 m in the eastern equatorial region where upwelling prevails, and the deepest penetration is deeper than 2000 m off Japan at an intersection of the Oyashio and Kuroshio currents. Overall, the North Pacific contains $14.7 \pm 4 \times 10^{15}$ g excess carbon. The total inventory of excess CO₂ in all oceans is being integrated. Such

¹Oregon State University, Corvallis.

an ocean-by-ocean inventory of excess CO₂ is important, since the assessment of the function of the oceans in the carbon cycle requires spatial resolution within individual oceans. The globally aggregated models do not yet have adequate resolution to discern the functional relationships that are needed to adequately assess the carbon cycle and changes in it due to CO₂-induced climate change.

Study of CO₂ Source and Sink Distributions with a Three-Dimensional Model (I. Y.-S. Fung¹)

Detailed measurements at several stations around the world (e.g., Mauna Loa in Hawaii and the South Pole) have shown marked seasonal and interannual variations in CO₂ abundance in the atmosphere. It is important for global carbon cycle research to investigate the potential information about CO₂ sources and sinks contained in such temporal and geographic variations. The purpose of this project is to compute the global distribution of atmospheric CO₂ for specified sources and sinks, using a three-dimensional model (the Goddard Institute for Space Studies three-dimensional atmospheric tracer transport model).

We have examined the seasonal perturbations of the terrestrial ecosystem as regulators of the major sources and sinks of CO₂ through satellites and surface air temperatures. Carbon dioxide absorption occurs in green leaves of plants where intercepted photosynthetically active radiation (IPAR) (0.4–0.7 μm) is absorbed by photosynthetic pigments. Polar-orbiting meteorological satellites of the National Oceanic and Atmospheric Administration use an advanced very-high-resolution radiometer (AVHRR) sensor to collect global radiation data at a 4-km spatial resolution. Estimates of IPAR absorbed by terrestrial vegetation obtained from satellite AVHRR data correlate with atmospheric CO₂ concentrations measured at surface recording stations, suggesting that satellite data can be used to quantitatively estimate seasonal and regional changes in CO₂ sources and sinks due to terrestrial photosynthesis. The magnitudes of response of atmospheric CO₂ to natural variations of components of CO₂ sources and sinks resolved with satellite data (e.g., variations due to the 1982–1983 El Nino–Southern Oscillation event) are being estimated.

Intramural Research

Sensitivity and Uncertainty Analysis of a Model of Forest Development (V. H. Dale, H. I. Jager, and R. H. Gardner)

A model of forest development is being used to estimate the influences of natural and anthropogenic disturbances on forest dynamics, including the effects of climate change and increasing levels of CO₂. Sources of error in the predictions of this model have been explored, using sensitivity and uncertainty analyses. Errors can occur as a result of the structure of the model, the sensitivity of the parameters, and/or an inadequate representation of the natural variability of the system.

The first steps in the sensitivity and uncertainty analysis of the forest growth model have been completed. The analytical sensitivity analysis takes advantage of the modular structure of the forest model by considering the sensitivities of the optimal growth module independent of other subcomponents of the model. Optimal tree growth in the model is most sensitive to the maximum diameter for a species. Future steps include identifying the sensitivities of the realized growth of trees by examining the effects of light, soil moisture, competition, temperature, and nutrient conditions.

¹Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York.

Examination of errors in the representation of the natural variability in the system focuses on spatial heterogeneity. The greatest sources of aggregation errors are found in those forest types which have the highest projected volume of aboveground stem wood per area and which cover the greatest land area. Model projections of aboveground stem wood volume for a county after 25 years of stand development fall within 80% overlap of the mean and variance of the measured volume.

Modeling the Seasonality of Terrestrial Contributions to Atmospheric CO₂ (D. L. DeAngelis and A. W. King)

Ecological models of the seasonal exchange of CO₂ between the atmosphere and the terrestrial biosphere are needed to help interpret and understand the current changes in atmospheric CO₂ concentration and to make predictions concerning long-term changes in the future. In response to this need, a set of site-specific models of seasonal terrestrial carbon dynamics was assembled from open-literature sources. Nine are models of natural ecosystems, and the tenth is a simulation of an agricultural system. The collection was used as a basis for the development of biome-level models of the earth's principal terrestrial biomes, or vegetation complexes. The primary difficulty associated with this approach is the problem of extrapolating the site-specific models across large regions having considerable biotic, climatic, and edaphic heterogeneity. Two methods of extrapolation were tested.

The first approach—a simple extrapolation that assumed relative within-biome homogeneity—generated CO₂ source functions that differed dramatically from published estimates of CO₂ exchange. The differences were so great that this simple extrapolation was rejected.

The second extrapolation explicitly incorporated within-biome variability in the abiotic variables that drive seasonal biosphere-atmospheric CO₂ exchange. Simulated site-specific CO₂ dynamics were treated as a function of multiple random variables (i.e., the model-driving variables). The predicted regional CO₂ exchange is the computed value of the simulated site-specific exchanges expected for that region times the area of the region. The extrapolation was tested for the circumglobal latitude belt between 64°N and 90°N. The test involved the regional extrapolation of a tundra and a coniferous forest carbon exchange model. Comparisons between the CO₂ exchange estimated by extrapolation and the published estimates of regional exchange for the latitude belt support the appropriateness of the extrapolation technique used. Extrapolation by mathematical expectation is a promising technique for extrapolating from site-specific models to regional and biome-level models.

CO₂ Enrichment and Mineral Nutrition of White Oaks (R. J. Norby, E. G. O'Neill, and R. J. Luxmoore)

The prominent role of forests in global photosynthesis suggests that an increase in carbon uptake and storage by forest vegetation could lower the airborne fraction of CO₂ from fossil fuel emissions. However, there is uncertainty as to whether the growth response to CO₂ enrichment of forest trees in infertile habitats will be similar to that observed in plants well supplied with nutrients. We have used controlled-environment chambers with regulated CO₂ atmospheres to test the hypothesis that plants, in this case white oak (*Quercus alba* L.) seedlings, grown under elevated levels of CO₂ will be able to acquire more mineral nutrients from the soil and thereby alleviate nutrient limitations to CO₂-induced growth enhancement. One-year-old, dormant seedlings were planted in pots containing a nutrient-poor forest soil and were grown without added fertilizer in

growth chambers in which the atmospheric concentration of CO₂ was maintained at near-ambient levels (362 µL/L) or at 690 µL/L. Growth, water use, and nutrient uptake were measured over 40 weeks.

The seedlings in both treatments became severely nitrogen deficient, and many leaves senesced and abscised. Nevertheless, growth was substantially enhanced in response to CO₂ enrichment. Plants grown in elevated CO₂ were 85% greater in dry weight than those grown in ambient CO₂, with the greatest increases occurring in fine roots and tap roots. The uptake of most nutrients increased with increases in CO₂ concentration, and phosphorus and potassium uptake increased in proportion to growth. The total uptake of nitrogen, sulfur, and boron, however, was not affected by CO₂; therefore, tissue concentrations of these nutrients were significantly lower in plants grown in elevated CO₂. An increase in nutrient-use efficiency with respect to nitrogen was apparent in that greater proportions of the limited nitrogen pool in the CO₂-enriched plants were in metabolically active tissue (fine roots and leaves) and lesser proportions were in storage tissue and abscised leaves.

The results demonstrate that a short-term growth response to CO₂ enrichment is possible in nutrient-limited systems, and that the mechanisms of response may include either increased nutrient availability in soil and uptake by roots or increased metabolic or physiological efficiency of nutrient use within the plant. However, a consequence of the increased nitrogen-use efficiency and greater wood production in CO₂-enriched plants was a lower amount of translocatable nitrogen in perennial woody tissue. Unless CO₂ enrichment increases the uptake of nitrogen from soil, the total amount of nitrogen available for new growth would be less in elevated than in ambient CO₂, and the growth response to CO₂ enrichment would be expected eventually to decline from what was observed in our relatively short-term experiment.

Changing Carbon Storage and Carbon:Nitrogen Ratios in Cultivated Soil (W. M. Post and L. K. Mann)

The interaction of nutrient availability, biomass production, and changes in carbon storage and release in soils under agricultural production remains under investigation. Compilation of previously published data indicated two major trends: (1) carbon loss from soil as a result of agricultural practices is related to the initial carbon concentration (i.e., soils high in carbon lose large amounts of carbon, whereas soils initially low in carbon tend to gain small amounts), and (2) most agricultural soils lose <20%, or 1 to 3 kg/m², of their original carbon. The suitability of using these results to estimate carbon losses over large regions was enhanced by adding data from the Soil Conservation Service. These data were collected to a depth of 100 cm and thus provided better estimates of carbon changes in the biologically active part of the profile. In addition, many samples included bulk density measures. Although some agricultural soils remained underrepresented, these data covered a greater spectrum of soil groups than previously analyzed.

After cultivation, all soil suborders with at least three pairs of samples (except Orthids and Ochrepts) averaged less carbon storage to a depth of 100 cm than before cultivation. However, differences were significant in only 4 of the 13 suborders because of high sample variability. For the combined data source, regression relationships of average suborder carbon storage to 100 cm in cultivated soil as a function of carbon storage in uncultivated soil was as follows: cultivated soil carbon (kg/m²) = 0.85 + 0.80 × uncultivated soil carbon (kg/m²) (r² = 0.96). This regression indicated that the maximum average losses of carbon were 20%, with slight gains in carbon at initial values

of $<4 \text{ kg/m}^2$. The average losses were 0.5 to 2.0 kg/m^2 from most agricultural soils, which had an initial carbon content of 5 to 15 kg/m^2 .

Analysis of nitrogen change in relation to carbon change in the previously published paired-plot comparisons demonstrated similar behavior of nitrogen and carbon. Approximately 50% of the samples that lost carbon also lost nitrogen, and an additional 10% of the samples gained both carbon and nitrogen. However, $\sim 20\%$ of the samples either lost carbon and gained nitrogen or gained carbon and lost nitrogen. We had initially hypothesized that changes in carbon and nitrogen would be closely linked, but these results make the relationships between these elements unclear in agricultural systems. Most samples showed a decrease in carbon:nitrogen ratios, but the overall pattern of changes in carbon:nitrogen ratios was similar to that of carbon and nitrogen considered separately: initially high carbon:nitrogen ratios tended to decrease, and initially low carbon:nitrogen ratios increased. Within the two groups represented by the largest number of samples (Alfisols and Mollisols) different behavior of carbon:nitrogen ratios was observed: Mollisols showed very little change in carbon:nitrogen ratios, whereas the carbon:nitrogen ratios decreased in Alfisols.

Seasonal Variability of pCO_2 in the Northern Atlantic Surface Water (T.-H. Peng)

The high-latitude northern ocean is one of the most critical areas for ventilation of the global deep oceans. In the Norwegian, Greenland, and Iceland seas, the surface water, which has exchanged O_2 , heat, and CO_2 with the atmosphere, sinks during the winter cooling and flows southward into the Atlantic where it is joined by the newly ventilated Labrador Sea water to form the saline North Atlantic Deep Water. Thus, the ventilation processes occurring over the high-latitude North Atlantic waters provide a direct transport pathway between the atmosphere and the deep oceans of the world.

The pCO_2 in the surface waters of the Iceland, Greenland, Norwegian, and Labrador seas and the North Atlantic Ocean was measured during the 1957 International Geophysical Year (IGY), the 1972 Geochemical Ocean Sections Study (GEOSECS), and the 1981 Transient Tracers in the Ocean/National Academy of Sciences (TTO/NAS) expeditions. These measurements were made mostly during the summer months. The results indicated that the surface waters had substantially lower pCO_2 values than the atmosphere, and hence were strong sinks for atmospheric CO_2 . However, using the total $\text{CO}_2\text{:O}_2$ and alkalinity: O_2 ratios for the deep water, it was estimated that the initial pCO_2 in seawater at the time of atmospheric exposure of subsurface waters in the winter must have been $\sim 1.50 \text{ Pa}$ greater than the values observed during the summer months at the corresponding temperatures. This suggests that this region of the northern ocean is a weak sink or even a mild source. It is clear that seasonality plays an important role in determining the sink or source of CO_2 in this high-latitude region, which is the site of formation of the major deep waters of the world ocean.

The seasonal variation in the temperature, salinity, mixed-layer depth, and pCO_2 in seawater and in the concentrations of total CO_2 , O_2 , and nutrients in surface water at a station located $\sim 193 \text{ km}$ south of the Iceland-Greenland sill was monitored during a 2-year period (March 1983 through May 1985) by a cooperative program between the Marine Research Institute of Reykjavik, Iceland, and the Lamont-Doherty Geological Observatory of Columbia University. It was observed that during the summer the pCO_2 and the concentrations of total CO_2 and nutrients in surface water were at their annual lows, whereas O_2 was at its annual high. This situation was reversed during the winter. The seasonal variation is attributed mainly to the high photosynthetic utilization rate of carbon

and nutrients in a strongly stratified and shallow mixed layer during the summer. The winter observations are attributed to the upward transport, through deep convective mixing, of deep water that is rich in CO_2 and nutrients released by oxidative decomposition of organic matter.

A vertically one-dimensional, two-box ocean model has been constructed to simulate the observed seasonal variations. In this model, the ocean is divided into an upper mixed layer and a deep-water layer, with the former exchanging CO_2 and O_2 with the atmosphere. The water mixing between the two boxes is assumed to occur as their boundary is seasonally displaced up and down. Photosynthetic products are characterized by a fixed P:N:C: O_2 stoichiometric ratio. They fall into the deep-water box where the nutrients are then released by oxidative decomposition. It is shown that the model yields the seasonal variation in carbon and O_2 values consistent with the observations.

References

- Trabalka, J. R. (ed.) 1985. Atmospheric carbon dioxide and the global carbon cycle. DOE/ER-0239. U.S. Department of Energy, Washington, D.C.

7. CARBON DIOXIDE INFORMATION CENTER

M. P. Farrell

J. B. Anderson ¹	D. E. Fowler	D. B. Miller ³	S. L. Schuhardt ²
T. A. Boden	H. Hattemer-Frey ³	E. E. Mitchell ⁴	P. N. Spring ²
P. F. Carfagna ²	V. N. Joyce	T. R. Nelson ⁵	D. M. Stokes
R. M. Cushman	P. C. Kitchin	F. M. O'Hara ⁶	C. E. Todeschini ⁷
R. M. Eller ²	R. E. Millemann	S. E. Reynolds ⁴	T. W. White

Introduction

The objective of the Carbon Dioxide Information Center (CDIC) is to compile, evaluate, and distribute CO₂-related information in support of the U.S. Department of Energy's Carbon Dioxide Research Division (CDRD). To accomplish this objective, CDIC identifies researchers' needs for data and computer hardware, software, and languages; obtains, evaluates, and ensures the quality of information; and works with other national and international data centers as well as individual researchers to promote and facilitate the exchange of data.

CDIC has two types of functions: (1) analyses of data and other types of information and (2) distribution of CO₂-related information. For the first function, CDIC evaluates and ensures the accuracy of many types of information, including numeric data and computer models. CDIC also engages in studies such as estimating the effects of a rise in sea level on coastal resources and evaluating the use of sound to analyze multivariate data.

For the second function, CDIC serves as CDRD's information distribution center. In 1986 CDIC received 2200 requests for different types of information. In response to many of these requests, 5575 reports and 504 numeric data and computer model packages were distributed. In addition, 13 searches of CDIC's Bibliographic Information System (a computerized bibliography on CO₂) were performed, requiring the evaluation of 3000 references. As an additional service for CDRD, CDIC maintains a directory that lists ~3100 researchers and policy makers from 150 countries.

Many of CDIC's activities continue from year to year—for example, evaluating and packaging numeric data and computer models, expanding the Bibliographic Information System, and examining the effects on resources of a change in the concentrations of atmospheric CO₂. CDIC also works on special projects for CDRD. (A special project is one in which CDIC helps develop the ground-work.) One project that began in 1985 and continued through 1986 was a collaborative research project with the People's Republic of China and the U.S. Department of Energy (DOE). CDIC developed and implemented a computer system for facilitating the exchange of >64 million data elements and has provided continuing technical personnel support for the research. Another project

¹Visiting staff, Science Teachers' Research Involvement for Vital Education Program, Oak Ridge Associated Universities.

²Oak Ridge Associated Universities undergraduate research intern.

³Graduate student, Miami University, Oxford, Ohio.

⁴University of Tennessee, Knoxville.

⁵Computing and Telecommunications Division, ORNL.

⁶Subcontractor.

⁷Visiting scientist, International Atomic Energy Agency, Vienna.

in 1986 was developing the initial draft plan for one of CDRD's new program areas, Resource Analysis. The objective of this program area is to direct research that will enable CDRD to develop policy options to enhance or lessen the effects of atmospheric CO₂ on resources. The research identified in this plan will support CDRD's program objective of quantifying the effects of increased atmospheric CO₂ concentrations and CO₂-induced climate changes on climate systems, agroecosystems, energy systems, and resources important to mankind.

The following sections discuss many of CDIC's activities during FY 1986.

Data and Information Analyses

Numeric Data and Computer Model Packages

CDIC increased its numeric data package (NDP) and computer model package (CMP) total to 22 by assembling 4 NDPs and 1 CMP during FY 1986. Packages consist of an abstract; a data listing; a magnetic tape, floppy disk, or microfiche; a data retrieval program; graphical displays of the data (NDPs only); and pertinent literature. As a part of packaging activities, a CDIC staff member wrote a paper identifying the criteria that will henceforth be followed when selecting numeric data bases for packaging. The criteria will also be used to determine a priority list for future packaging activities.

The four NDPs are Worldwide Organic Soil Carbon and Nitrogen Data (NDP-018); United States Historical Climatology Network (HCN) Serial Temperature and Precipitation Data (NDP-019); Atmospheric CO₂ Concentrations—Mauna Loa Observatory, Hawaii, 1958–1986 (NDP-001/R1); and Transient Tracers in the Oceans (TTO)—Hydrographic Data and Carbon Dioxide Systems with Revised Carbon Chemistry Data (NDP-004/R1).

The CMP is an IBM PC (personal computer) version of the IEA/ORAU [Institute for Energy Analysis/Oak Ridge Associated Universities] Long-Term Global Energy–CO₂ Model. This model contains the computer code for making projections about many aspects of global energy and CO₂ emissions at 25-year intervals from 1975 to 2100. CDIC also evaluated the ARTUS [Arctic Tundra Simulator]–CO₂ Model (produced at San Diego State University) and the GLYCIM Model (a crop simulator model produced at Mississippi State University) for their potential as CMPs.

Global Climate—Resource Studies

CDIC is developing methods for, and participating in, studies of present and future global climate patterns and regional analyses of the effects of climate change on world resources. At the Joint Meeting of the European Geophysical Society and the European Seismological Commission (Kiel, Federal Republic of Germany, August 1986), a CDIC staff member presented a paper titled "Climate Predictions and Regional Resource Analysis," in which the relationship between general circulation model (GCM) grid cell size and resource heterogeneity was examined. CDIC's work with GCMs has included (1) preparing maps of four GCM grids (Goddard Institute for Space Studies, National Center for Atmospheric Research/Geophysical Fluids Dynamics Laboratory, Oregon State University, United Kingdom Meteorology Office) and a 0.5° × 0.5° grid superimposed on nine resources (yield of corn, wheat, sorghum, and soybeans; population density and percent of population at least 65 years old; percent of forest cover; percent of land irrigated; water resource region) for the United States (Fig. 7.1); (2) collecting the output from four GCMs (Goddard Institute for Space Studies, National Center for Atmospheric Research, Geophysical Fluids Dynamics

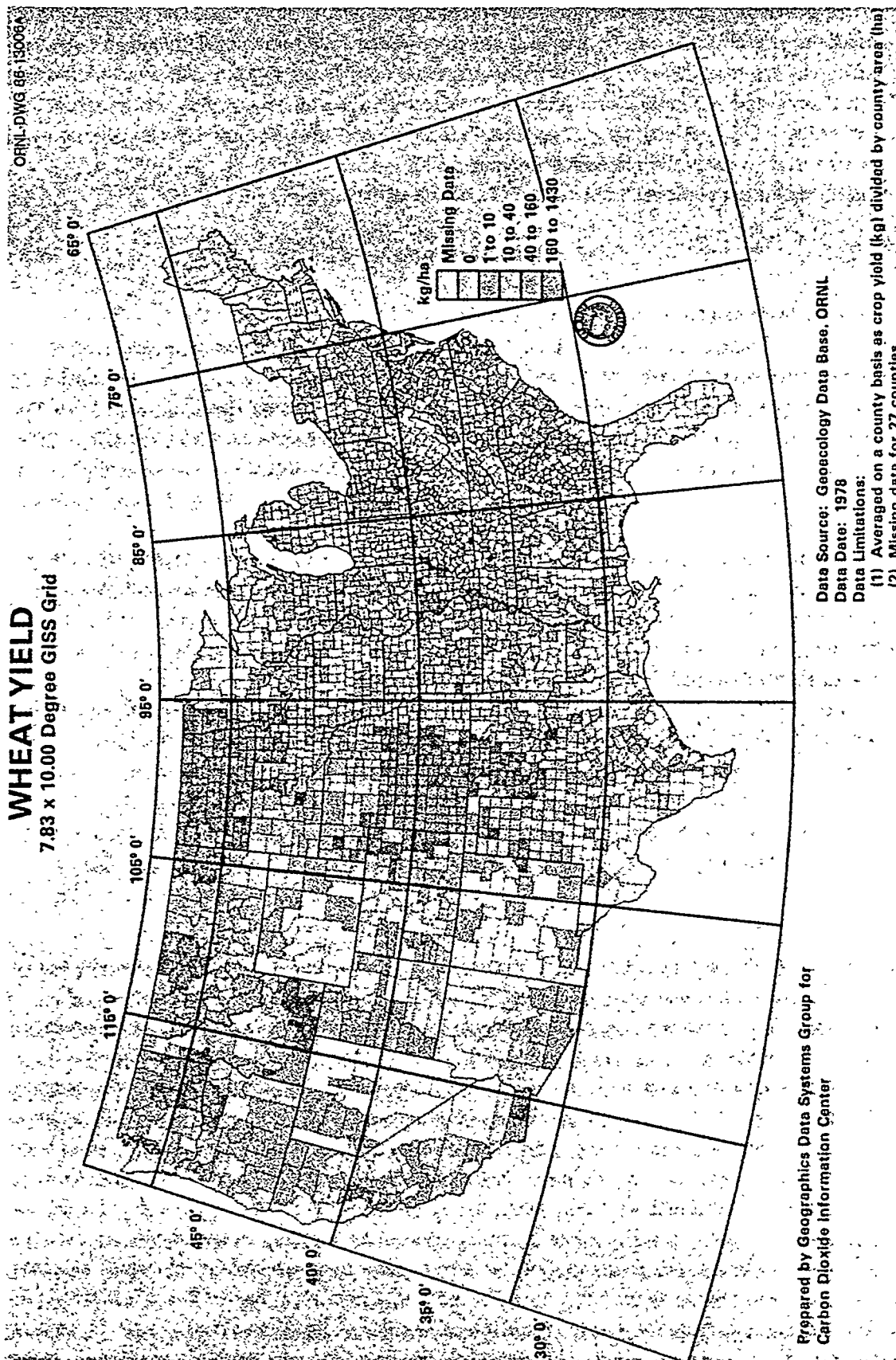


Fig. 7.1. The Carbon Dioxide Information Center uses GEOECOLOGY data and climate-model grids to study methods for predicting the effects of climate change on resources.

Laboratory, Oregon State University/Lawrence Livermore National Laboratory) and distributing it to the intercomparison working group (Lawrence Livermore National Laboratory, Atmospheric and Environmental Research, State University of New York at Stony Brook); and (3) producing a county-level approximation of the Goddard Institute for Space Studies GCM grid and demonstrating the usefulness of this approximation by using GEOECOLOGY county-level crop data and climate-yield regressions to predict changes in U.S. soybean production under the doubled-CO₂ climate scenario of the Goddard Institute of Space Studies GCM.

On another project, CDIC has been studying resources at risk from a possible rise in sea level. A data base of multisector environmental data integrated with topographic data is being developed to permit such an analysis. Also, CDIC is coordinating a related study (with the Geographics Data Systems Group of the Computing and Telecommunications Division, Oak Ridge National Laboratory) to calculate and map, on a global basis, the land and other natural and physical resources that could be flooded by a specified sea level rise of up to 10 m. The applicability of a global topographic data base that is needed for this study has already been tested by validation in Connecticut.

Music Analysis

The impetus for this research project stemmed from a *Science News* article titled "The Sound of Data" (Peterson 1985), which discussed the use of computer-generated sound to analyze data. This novel approach is based on the premise that individuals can hear differences in data patterns more readily than they can perceive these differences through visual representations (such as graphs or charts). Thus, converting data into sound offers a unique and possibly better way of analyzing some types of data. In addition, sound can be used as an exploratory tool to discern patterns, which can then be tested by traditional time series statistical models.

CDIC developed a research plan for using computer-generated sound to analyze long-term climate data. To begin the project, CDIC purchased sound-generating equipment that could use complex audio signals to analyze multivariate data (Fig. 7.2):

- two Yamaha FM tone generators (nonkeyboard synthesizers)
- one Yamaha MIDI (musical instrument digital interface) expander, which allows the computer to communicate with both synthesizers at the same time
- one Yamaha 6-input, 2-output dead mixer, which allows output from both synthesizers to be combined into one amplifier
- one IBM PC MIDI interface
- one Luxman L-400 55-watt amplifier
- one Nakamichi BX-300 cassette deck
- two pairs of Stax SR-30 headphones with associated preamplifier
- one pair of KEF C-60 speakers

Two computer programs were developed: one program allows the IBM PC computer to communicate with and control the synthesizers, and the other program is used to convert climatic data into musical notes.

ORNL Photo 1791-86

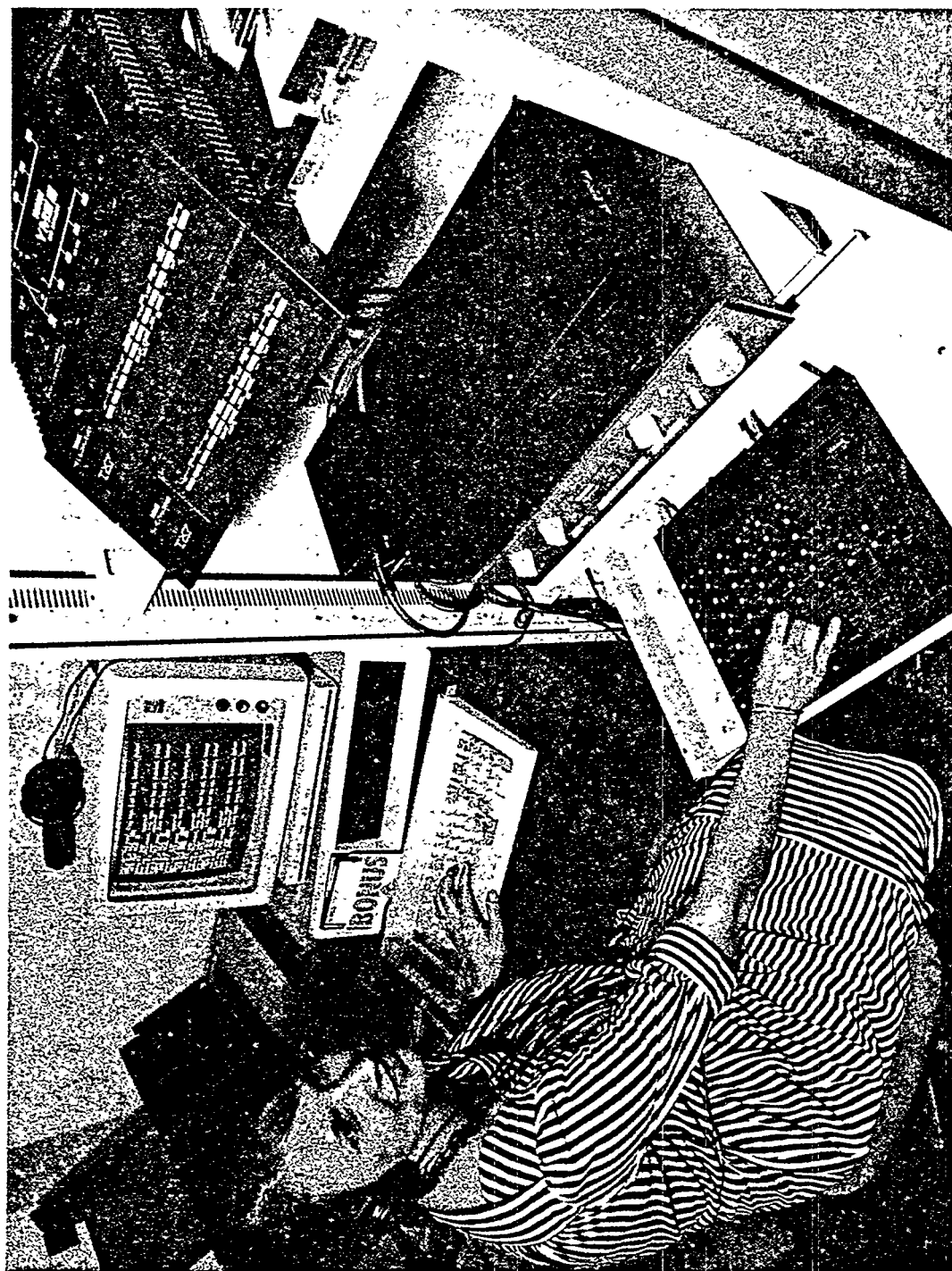


Fig. 7.2. The Carbon Dioxide Information Center is exploring the use of computer-generated sound to analyze complex data.

Several data sets were converted into sound, and CDIC began using sound to explore three temperature data sets. CDIC also investigated how changes in pitch, tempo, instrument, and timbre affect one's ability to hear similarities or differences in data patterns.

Climatic Indices

CDIC is in the process of publishing An Annotated Inventory of Climatic Indices and Data Sets as a CDRD technical report. The publication describes 34 prominent climatic indices and provides an annotated listing and bibliography of other indices. The objective of the publication was to present indices that would be useful to scientists working in diverse areas of CO₂-climate research and to those interested in climate research results for other applied studies. The indices are grouped into ten subject categories: (1) Global/Hemispheric Data Sets (monitoring a climatic variable for one or both hemispheres); (2) Marine Data Sets (sea surface temperature, marine air temperature, and global sea level indices); (3) Long-Term Regional and Local Temperature and Precipitation Data Sets (indices with more than 25 years of data for cities, states, countries, and continents); (4) Atmospheric Constituents Data Sets (describing the climatic effects caused by the presence of volcanic dust, carbon dioxide, and trace gases in the atmosphere); (5) Upper Air Data Sets (monitoring wind patterns, outgoing long-wave radiation, stratospheric and tropospheric temperatures, and circulation patterns); (6) Southern Oscillation-El Nino Data Sets (describing the Southern Oscillation and El Nino phenomena and related phenomena, such as seasonal changes in atmospheric pressure and equatorial sea surface temperatures); (7) Solar Data Sets (indices that describe the climatic changes associated with variations in the sun's structure and radiant flux); (8) Proxy Data Sets (derived by means other than direct measurement, such as the use of tree-ring measurements to reconstruct climatic changes that occurred before instrumental measurements were taken); (9) Lake Levels and River Flows Data Sets (describing climatic variations associated with fluctuations in the levels of African lakes, the Great Salt Lake, the Great Lakes, and the Nile River); and (10) Snowcover and Sea Ice Extent Data Sets (monitoring variations in the amount of arctic and antarctic snow cover and sea ice).

For each index, information is provided on primary references, application, background, calculation, temporal and spatial resolution, units of measurement, period of record, reliability, comparisons with other indices, sponsors, availability of data, and additional references. This collection of indices is not an all-inclusive inventory; it is intended as a first attempt at providing a climate indices reference publication for CO₂-climate researchers. CDIC hopes to have it continuously updated as more information becomes available.

Information Distribution

Request and Response Records System

The Request and Response Records System is used by CDIC to record and track all requests for information. The 2200 requests received at CDIC in FY 1986 were an increase of more than 150% over those received in FY 1985. Almost all types of information distribution activities increased, including the distribution of DOE technical reports, CDIC reports, miscellaneous articles, and numeric data and computer model packages. In response to many of these requests, 5575 reports were distributed. This increase is largely accounted for by the distribution of CDRD's state-of-the-art reports, which explain past and current CO₂ research as well as provide information

about what types of research are needed in the upcoming years. The state-of-the-art reports were distributed to persons in CDIC's World Directory of CO₂ Researchers and Policy Makers, which lists ~3100 persons from 150 countries. The directory contains specialized mailing lists that are sorted according to the persons' affiliations and interests in the CO₂ issue.

Bibliographic Information System

CDIC's Bibliographic Information System (BIS) contains ~9100 references, an increase from 8000 at the end of FY 1985. Citations are entered into BIS according to the CDRD program area classifications: climate, carbon cycle, vegetation response, and indirect effects. CDIC is working with DOE's Office of Scientific and Technical Information to merge BIS into DOE's Energy Data Base.

During FY 1986, CDIC evaluated two other data bases, the Climate and Society Database and the Weather and Climate Hazards Database, which were compiled by the Natural Hazards Research and Applications Information Center (University of Colorado). All of the records relevant to CO₂ were entered into BIS.

CDIC publications pertaining to BIS that were published in FY 1986 include the Carbon Dioxide Information Center Thesaurus (ORNL/CDIC-5) and the Subject Keywords Index for the Carbon Dioxide Information Center's Bibliographic Information System (ORNL/CDIC-15).

Communications

CDIC publishes a semiannual newsletter, *CDIC Communications*, which is distributed to all persons listed in CDIC's directory. (The number of persons listed in the directory increased from 1900 to 3100 by the end of FY 1986.) *CDIC Communications* informs CO₂ researchers and policy makers of current research, recent policy decisions, CDIC services, and new CO₂-related publications and meetings.

Networking

One of CDIC's objectives is to work with data centers, universities, and individual researchers to promote and facilitate the exchange of data. During FY 1986, CDIC staff members engaged in several activities toward this end, including attending symposia and workshops; working with several climate centers such as the Goddard Institute for Space Studies and the Geophysical Fluids Dynamics Laboratory to obtain and distribute GCM data; and working with many researchers to obtain and distribute important CO₂ data sets such as the Wigley-Jones temperature anomaly data set, portions of the National Climatic Data Center's 1000-station meteorological data base, and the cloud cover atlas published by the Cooperative Institute for Research in Environmental Sciences. Other activities included meetings with staff of the U. K. Meteorological Office (Bracknell, England), the European Centre for Medium Range Weather Forecasts (Reading, England), the National Climatic Data Center (Asheville, North Carolina), and the Institute for Energy Analysis/Oak Ridge Associated Universities (Oak Ridge, Tennessee) to discuss the exchange of data and other information.

Special Projects

People's Republic of China

The People's Republic of China Academia Sinica and the U.S. Department of Energy's CDRD are collaborating on an atmospheric CO₂ research program. The two countries are studying the effects of increasing atmospheric CO₂ on climate on many scales, including global, regional, and local. This joint effort provides opportunities for scientists of both countries to share information, which will lead to a better understanding of the earth's climate systems and, possibly, to improved long-range weather and climate predictions.

Both countries will benefit from this program. The People's Republic of China will gain access to the existing U.S. climate data base and the computing facilities for research. The United States will gain access to China's data bases, which are unique because of the length of time covered, making them a valuable tool for validating models and evaluating regional climate change.

The program will fulfill two major needs in the study of CO₂-induced climate change: (1) the need for climate models to predict possible regional climate change, given a global CO₂-induced climate change, and (2) the need for data to validate these models.

CDIC's role was to develop and implement the computer system being used on the China project. CDIC continues to provide technical personnel support. In addition, CDIC is developing a standard operating procedure for data exchange and plans to begin a data newsletter to keep the principal researchers up to date on each other's activities in the two countries.

Resource Analysis Plan

CDRD is in the process of reorganizing its research program. The overall objective of the program is to quantify the effects of increased CO₂ concentrations and CO₂-induced climate changes on climate systems, agroecosystems, energy systems, and resources important to mankind.

As part of this reorganization, CDIC developed the initial draft plan for a new program area called Resource Analysis. The objective of this program area is to direct research that will enable CDRD to develop policy options to enhance or lessen the effects of atmospheric CO₂ on resources. This research will support CDRD's overall program objective.

Coordination, Control, and Communication

The Coordination, Control, and Communication System, called C³, is a computer-based management tool that is used to analyze the CDRD research program as a whole or the individual details of the program and to show the relationships between the program components; it also provides a means to encode and evaluate the uncertainties in the CDRD program. C³ contains information about each research project, including contract and product information and statistical measurements for the research.

CDIC evaluated many types of computer systems and recommended the one being used by CDRD to implement C³. After selecting the computer hardware and software, CDIC designed the system, wrote the computer codes, and developed the graphics for it. The system contains menus so that program managers can quickly locate needed information and view the status of their areas in relation to the entire program. The continued development of this system was temporarily stopped because CDRD is reorganizing its entire research program. Once the reorganization is complete, CDIC will adjust C³ to accommodate the changes.

Sea Level Rise

The potential for a rise in the global sea level caused by a CO₂-induced climate change has received much attention in recent studies by the Polar Research Board (1985), the Environmental Protection Agency (Hoffman, Keyes, and Titus 1983), and the National Research Council (1983). As these studies reflect, the trend in sea level rise is exceedingly difficult to estimate because there are multiple sources, the data base is incomplete, and the data provide only an ambiguous delineation of cause and effect.

Since 1983, the Polar Research Board, the Environmental Protection Agency, and the National Research Council have made very different projections known to the public. Because of the differing views, CDRD decided it was necessary to write a paper on sea level rise that explained CDRD's position. CDIC's role was to help CDRD develop a format for the position paper and to provide technical input. This paper was intended to be the first of a series of CDRD position papers on various topics.

References

- Hoffman, J. S., D. Keyes, J. G. Titus. 1983. Projecting future sea level rise: Methodology, estimates to the year 2100, and research needs. U.S. Environmental Protection Agency, Washington, D.C.
- National Research Council. 1983. Changing Climate. National Academy Press, Washington, D.C.
- Peterson, I. 1985. The sound of data. *Sci. News*. 127:348-350.
- Polar Research Board. 1985. Glaciers, Ice Sheets, and Sea Level: Effect of a CO₂-induced Climatic Change. National Academy Press, Washington, D.C.

PART III. EXTRAMURAL ACTIVITIES

8. EDUCATION

S. E. Herbes and C. T. Hunsaker

The Environmental Sciences Division (ESD) maintains strong relationships with universities and other research institutions, and through these interactions we are able to augment staff capabilities in key scientific areas. Universities also provide valuable assistance by supplying summer staff and interns for short-term positions and by assisting us in our search for high-quality people to fill permanent staffing needs. Our education programs are coordinated through the Education Committee, whose role is to advise Division management on questions of education policy and to ensure that the Division's programs continue to provide exceptional opportunities for student involvement while meeting the Division's programmatic objectives.

Seminar Program

P. J. Mulholland

During the past year, the Seminar Committee offered a diverse program of guest lectures to inform ESD staff and other interested members of the local scientific community about topics of general interest in the environmental sciences (Table 8.1). The Seminar Committee relies largely on suggestions from ESD staff members concerning the selection of outstanding speakers.

Table 8.1. Seminar speakers, Environmental Sciences Division:
October 1, 1985–September 30, 1986

Date	Speaker	Title
10/2/85	Joseph H. Welsh GKN Hayward Baker Odenton, Maryland	Ground modification and stabilization
10/14/85	Douglas A. Shaefer Dartmouth College Hanover, New Hampshire	Physical, chemical, and biological processing of throughfall by forest canopies
11/11/85	Lawrence T. Thorne Winston Churchill Travelling Fellow National Coal Board London, England	Acid rain issues in the United Kingdom
12/17/85	John J. Stegeman Woods Hole Oceanographic Institute Woods Hole, Massachusetts	Enzymes as indicators of environmental stress and toxicity

Table 8.1. (continued)

Date	Speaker	Title
1/20/86	Jane M. Petite Department of Horticulture Science University of Guelph Guelph, Ontario, Canada	Water relations and dry matter partitions of air-pollutant- stressed vegetable crops
1/21/86	Dan Binkley School of Forestry and Environmental Studies Duke University Durham, North Carolina	Ion exchange resin bags: Factors affecting estimates of nitrogen availability
1/21/86	David H. Dawson Forestry Research Consultant Rhinelander, Wisconsin	National policy trends and implications for forestry
1/27/86	John A. Cherry University of Waterloo Waterloo, Ontario, Canada	Hydrology of low-permeability clayey deposits and waste disposal implications
1/30/86	Mary Beth Adams Department of Forestry North Carolina State University Raleigh, North Carolina	Starch in roots and foliage of loblolly pine: Effects of season, site, and fertilization
2/10/86	Dennis Knight Department of Botany University of Wyoming Laramie, Wyoming	Parasites, lightning, and the vegetation mosaic in wilderness landscapes
2/18/86	Christine Shoemaker Department of Environmental Engineering Cornell University Ithaca, New York	Optimization methods for identifying cost-effective solutions to groundwater pollution
2/19/86	Christine Shoemaker Department of Environmental Engineering Cornell University Ithaca, New York	Integrating population dynamics with economic assessments in integrated pest management: A modeling approach

Table 8.1. (continued)

Date	Speaker	Title
2/26/86	Alvin L. Young Office of Sciences and Policy Executive Office of the President Washington, D.C.	The setting of science policy: A view from the White House Science Office
3/11/86	Patrick J. Flanagan Director, Ecology Program National Science Foundation Washington, D.C.	Microbial ecology and concerns of release of genetically engineered microorganisms
4/15/86	John W. M. Rudd Freshwater Institute Department of Fisheries and Oceans Winnipeg, Manitoba, Canada	Factors controlling methylmercury bioaccumulation in aquatic ecosystems
4/16/86	John W. M. Rudd Freshwater Institute Department of Fisheries and Oceans Winnipeg, Manitoba, Canada	Prediction of biological acid neutralization in lakes
4/18/86	Carmen J. Nappo Atmospheric Turbulence and Diffusion Division National Oceanic and Atmospheric Administration Oak Ridge, Tennessee	Thunderstorm-induced gravity waves and their effects on the stably stratified boundary layer
5/1/86	Edith Brown Weiss Law Center Georgetown University Washington, D.C.	Large-scale environmental issues and international law
5/12/86	G. Richard Holdren Northrup Services, Inc. Corvallis, Oregon	Reaction rate-surface area relationships during the early stages of weathering for feldspar group minerals
5/13/86	Richard A. Houghton Marine Biological Laboratory Woods Hole, Massachusetts	Terrestrial metabolism and seasonal amplitude of atmospheric CO ₂

Table 8.1. (continued)

Date	Speaker	Title
5/15/86	R. P. Betson J. M. Boggs Tennessee Valley Authority Engineering Laboratory Norris, Tennessee	Macrodispersion experiment: Report on a field experiment to investigate transport processes in a saturated groundwater zone
6/10/86	Richard A. Larson Institute for Environ- mental Studies University of Illinois Urbana, Illinois	Free radical photochemistry in natural waters
6/25/86	Eliana Amaral Instituto de Radioprotecao e Dosimetria Rio de Janeiro, Brazil	Activities of the Brazilian Radiation Protection and Dosimetry Institute

Undergraduate Education Program

C. T. Hunsaker

Several Oak Ridge National Laboratory (ORNL) and Oak Ridge Associated Universities (ORAU) programs for undergraduate student participation in ESD research and assessment projects provide a continuing opportunity for interaction between students and staff. Highly qualified undergraduates are selected from colleges and universities throughout the United States (Table 8.2). Students are assigned to individual ESD advisors who guide them through a summer- or semester-long experiment or project associated with one of the ESD programs. Each student is required to document the results in a report and present a seminar to the ESD staff. These experiences in research participation are designed to expose the student to the research process in a large laboratory. The greatest benefits to the students are frequently an expanded outlook on career opportunities in research and an understanding of practical approaches to research problems. During FY 1986, the total number of students participating in ESD's Undergraduate Education Program increased from 13 to 24.

Graduate Education Program

S. E. Herbes

ESD provides the opportunity for graduate and postdoctoral research consistent with the mission of ORNL. During this reporting period, a total of 34 students participated in graduate research in

ESD (Table 8.2). While maintaining the traditionally strong participation of the University of Tennessee Graduate Program in Ecology, ESD hosted graduate students from 15 other universities, many of them through the ORNL Summer Research Internship Program. In addition, three post-doctoral interns and one Wigner fellow pursued research studies as part of divisional programs.

Graduate research opportunities vary in length from internship of several months' duration to multiyear Ph.D. dissertation projects. Student research is guided by selected ESD staff members, one of whom serves on each student's university academic guidance committee. Tuition, fees, and stipends for some of the graduate students are provided through U.S. Department of Energy educational assistance programs administered through ORAU and the ORNL Office of University Relations. Many students are supported through ESD programmatic funds, and several are self-supported.

In addition to students in residence, ESD programs support graduate research at many of the universities with which subcontractual arrangements are maintained (Sect. 9).

Faculty Program

S. E. Herbes

ESD provides opportunities for professional educators to participate in collaborative research with Division staff. During this reporting period, four university faculty participated in summer or sabbatical research at ESD (three in the ORAU Faculty Summer Research Participation Program and one in the ORNL Summer Faculty Program), in addition to the many faculty members who visited ESD for workshops, seminars, or subcontract consultations (Table 11.1).

**Table 8.2. Universities represented by guests in residence at
Environmental Sciences Division during the period
October 1, 1985–September 30, 1986**

University	Under-graduate	Graduate	Post-graduate	Faculty	Program ^a
Albion College	1				GLCA/ACM
Ashland College	1				SRP
Auburn University			1		ORAU
Austin Peay State University	1				SRP
Beloit College		1			SRI
Birmingham- Southern College	2				SCUU
Calvin College				1	FSRP
Carleton College	1				GLCA/ACM

Table 8.2. (continued)

University	Under-graduate	Graduate	Post-graduate	Faculty	Program ^a
Carroll College	1				SRP
Earlham College	1				GLCA/ACM
East Tennessee State University				1	FSRP
Florida State University	1	1			SRP, GSRP
Fort Valley State College	3			1	SSP, SFP
Grinnell College	2				SRP, GLCA/ACM
Hiram College		1			SRI
Indiana University		2			SRI, sub- contract
Indiana University of Pennsylvania	1				SRP
Johns Hopkins University		1			GSRP
Knox College	1				GLCA/ACM
Lawrence University				1	FSRP
Maryville College		1			SRI
Millersville State College	1				SRP
Northern Arizona State University	1				SRP
North Carolina State College			1		ORAU
Peru State College		1			SRI
Purdue University		1			RWMP
State University of New York at Binghamton	1				SRP

Table 8.2. (continued)

University	Under-graduate	Graduate	Post-graduate	Faculty	Program ^a
Tennessee Technological University		1			SRI
University of California, Los Angeles		1			Subcontract
University of Minnesota			1		ORAU
University of North Carolina	1	1			SRP, GSRP
University of Tennessee					
Biology	1				SRP
Civil Engineering		1			Subcontract
Ecology		14			Subcontract
Environmental Toxicology		3			Subcontract
Geology		4			Subcontract
Wabash College	1				GLCA/ACM
Wells College	1				SRP
William and Mary College	1				SRI
	—	—	—	—	
Totals	24	34	3	4	

^aFSRP = Oak Ridge Associated Universities Faculty Summer Research Participation Program; GLCA/ACM = Great Lakes Colleges Association/Associated Colleges of the Midwest Oak Ridge Science Semester Program; GSRP = Oak Ridge Associated Universities Graduate Student Research Participation; ORAU = Oak Ridge Associated Universities Postdoctoral Program; RWMP = U.S. Department of Energy Radioactive Waste Management Practicum; SCUU = Southern College and University Union Oak Ridge Science Semester Program; SFP = Oak Ridge National Laboratory Summer Faculty Program; SRI = Oak Ridge National Laboratory Student Research Internship Program; SRP = Oak Ridge Associated Universities Student Research Participation Program; SSP = Oak Ridge National Laboratory Special Summer Program; Subcontract = Environmental Sciences Division subcontract with a university.

High School Science Teachers Program

S. E. Herbes

Several programs were instituted in FY 1986 to encourage and strengthen science education on the secondary school level by providing opportunities for teachers and students to participate directly in ORNL research projects. During summer 1986, three Tennessee high school teachers worked for 8 weeks in ESD through the ORAU High School Teachers Research Participation Program. In addition, an area high school senior performed studies at ESD on the physiological response of plants to air pollutants through the ORNL Special Honors Study Program for High School Students.

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Assist in the development of a national operational plan for acid precipitation effects research	Argonne National Laboratory	D. S. Shriner
Development of a proposal to DOE concerning aquatic linkages in the acidification of surface waters	Argonne National Laboratory	W. Van Winkle
Research to determine accurately the $^{13}\text{C}:^{12}\text{C}$ isotope ratio in atmospheric CO_2 over the past 150 years by analyzing the corresponding isotopic record in tree rings by removal of climatic interferences	Arizona, University of	C. C. Coutant
Research to determine the effect of the historical pattern of elevated atmospheric CO_2 levels on tree growth and forest productivity	Arizona, University of	D. C. West
Research on selection of lignocellulosic species for energy crops	Auburn University	J. W. Johnston
Fabrication of electronic dendrometers for use in field research with loblolly pine	Battelle Pacific Northwest Laboratories	S. B. McLaughlin
Research and development in application of in situ vitrification technology for low-level wastes	Battelle Pacific Northwest Laboratories	B. P. Spalding
DOE state-of-the-art report on global carbon cycle research	Battelle Pacific Northwest Laboratories	J. R. Coutant
Assist in developing a national operational plan for acid precipitation effects research	Battelle Pacific Northwest Laboratories	D. S. Shriner
Eucalyptus plantations for energy production in Hawaii	Bioenergy Development Corporation	J. W. Ranney

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Development of a three-dimensional transport model of the carbon cycle in the ocean	California, University of	C. C. Coutant
Assist in the biomass research project on hydrocarbons and energy from plants	California, University of Lawrence Berkeley Laboratory	J. W. Johnston
Support in storage and transfer of organic matter in terrestrial ecosystems, litter, and soil	California, University of	W. M. Post
Regional analysis of sedimentary rock resources and acidic deposition impacts	California, University of	D. S. Shriner
Monitor atmospheric CO ₂ levels	California, University of	M. P. Farrell
Test the HARM II site rating methods on DOE-sponsored sites	Camp, Dresser and McKee	L. W. Barnthouse
Phase I activities to develop a level II acid deposition assessment model	Carnegie-Mellon University	D. S. Shriner
The impact of acid precipitation on Piedmont forest soils	Clemson University	D. W. Johnson
Involvement with the National Atmospheric Deposition Program that requires sample analysis by a central analytical laboratory for comparability of data on atmospheric deposition on a national scale	Colorado State University	S. E. Lindberg
Analysis of southern hemisphere CO ₂ data in relation to variations in atmospheric circulation and sea ice conditions	Colorado, University of	C. C. Coutant
Screening and selection of herbaceous species for biomass production in the Midwest-Lake States	Cornell University	J. W. Johnston
Ecological effects of acidification on low-order woodland streams, with particular emphasis on the chemistry and effects of aluminum	Cornell University	J. W. Elwood

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Test the Harm II site rating methods on DOE-sponsored sites	Dames and Moore	L. W. Barnthouse
Field nutrient cycling research at the loblolly pine plantation in Duke Forest.	Duke University	E. A. Bondietti
Compile historical data on patterns of land use and vegetation cover for South Asia and Southeast Asia for the period 1700 to 1980 AD	Duke University	C. C. Coutant
Survey to delineate areas of contaminated sediment	EG&G, Inc.	C. B. Sherwood
Placement and maintenance of wells for sampling peat drainage waters	East Carolina University	J. F. McCarthy
Integrated forest study of effects of atmospheric deposition	Emory University	E. A. Bondietti
Support of study of groundwater flow	Emory University	S. H. Stow
Species screening and genetic selection at sites in Arizona, New Mexico, and Texas	Energy/Development International	L. L. Wright
SWSA-6 contaminant pathways analysis study and hydrologic modeling	Environmental Consulting Engineers	E. C. Davis
Eucalyptus for biomass production in Florida (part of DOE's Short Rotation Woody Crops Program)	Florida, University of	L. L. Wright
Technical support on National Surface Water Survey	Ford, Thornton, Norton, & Associates	R. J. Olson
Selection of lignocellulosic species for energy crops	Geophyta	J. H. Cushman
Perform specialized studies on incorporation of sulfur into soil organic matter	Georgia, University of	E. A. Bondietti

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Chemical analysis of plant, soil, and solution samples for the project Elevated CO ₂ Effects on Terrestrial Ecosystems	Georgia, University of	R. J. Luxmoore
Support of integrated forest study of atmospheric deposition	Georgia, University of	E. A. Bondietti
Provide assistance to the hydrofracture data base project at ORNL	Gerghy and Miller	D. D. Huff
Measuring changes in the forests of the Amazon basin	Hudson River Foundation	C. C. Coutant
Support in preparing reviews of specific hazardous and radioactive waste action	IT Corporation	R. M. Reed
Passage of salmonids (resident and migrating) through bulb turbines and their associated mortality	Idaho State University	G. F. Cada
The role of tropical forests in the global carbon cycle	Illinois, University of	C. C. Coutant
Provide high-quality student interns who are well suited to ESD programs	Indiana University	C. T. Hunsaker
Atmospheric deposition and canopy interactions studies	Institute of Ecosystem Studies	E. A. Bondietti
Breeding <i>Alnus</i> for intensive culture of biomass for energy (part of DOE's Short Rotation Woody Crops Program)	Iowa State University	P. A. Layton
DOE/industrial roles in biotechnology	JAYCOR	J. H. Cushman
Provide analysis and technical assistance for Herbaceous Energy Crops Program	JAYCOR	J. H. Cushman
Develop a technology transfer plan for ORNL's Biomass Production Program	JAYCOR	R. I. Van Hook

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Determination of the best species and management techniques for short-rotation production of fuel wood in the Great Plains	Kansas State University	P. A. Layton
Workshop on predicting responses of fish populations to acidification	Kilkenny Environmental Associates, Inc.	R. J. Olson
Comparison of pre- and postbomb radiocarbon in soils and soil fractions	Lamont-Doherty Geological Observatory, Columbia University	C. C. Coutant
Assessment of carbon dioxide sinks and sources in oceanic areas	Lamont-Doherty Geological Observatory, Columbia University	C. C. Coutant
Analysis of red spruce chronologies for anthropogenic pollutant effects	Lamont-Doherty Geological Observatory, Columbia University	S. B. McLaughlin
Assemble and evaluate oceanographic data in support of ocean model development	Lamont-Doherty Geological Observatory, Columbia University	C. C. Coutant
Research designed to identify and quantify principal sources and sinks of atmospheric CO ₂ on a global scale	Lamont-Doherty Geological Observatory, Columbia University	C. C. Coutant
Hydrological support of characterization and water quality monitoring well	MCI Consulting Engineers, Inc.	L. Hyde
Remote sensing of deforestation in the Amazon basin	Marine Biological Laboratory	C. C. Coutant
Development and testing of mathematical models for use in defining the role of terrestrial biota in the global CO ₂ cycle	Marine Biological Laboratory	C. C. Coutant
Technical support for Annual Meeting on Low-Level Waste Management	Maxima Corporation	W. H. Pechin

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Determining the effect of observed changes of atmospheric CO ₂ on tree and forest growth	Maxima Corporation	D. C. West
Internship program	Miami University	M. P. Farrell
Validation with field data and predictive application of the hydrological model FEWA	Miami, University of	E. C. Davis
Collect radiocarbon data from the Indian Ocean	Miami, University of	C. C. Coutant
Tree species and management strategies for biomass production in the Great Lakes states	Michigan State University	P. A. Layton
Integrated forest study of effects of atmospheric deposition	Michigan, University of	E. A. Bondietti
Soil analysis from a Minnesota soil chronosequence	Minnesota, University	A. M. Solomon
Recovery of soil carbon after agricultural abandonment and intensive forest management	Minnesota, University of	R. I. Van Hook
Use of wetlands for production of woody plants for fuels and petrochemical substitutes	Minnesota, University of	J. W. Johnston
Workshop on field sampling techniques for collection of contaminated materials	NUS Corporation	N. H. Cutshall
Computer support to run models of the atmosphere	National Aeronautics and Space Administration	C. C. Coutant
Temperature and precipitation in the United States	National Oceanic and Atmospheric Administration	M. P. Farrell
A study of the role of the oceans in the global carbon cycle through modeling exercises	New Hampshire, University of	C. C. Coutant
Provide model of the global cycles of carbon, nitrogen, and phosphorus	New Hampshire, University of	W. R. Emanuel

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Atmospheric deposition research at Whiteface Mountain	New York, State University of	E. A. Bondietti
Site preparation and support for research site	New York, State University of	E. A. Bondietti
Collect data to test alternative hypotheses of increased acidification and fish population declines in the Adirondack region	New York, State University of	R. J. Olson
Species selection and silvicultural systems for producing fuels from woody biomass in the southeastern United States	North Carolina State University	L. L. Wright
Processing benthic invertebrate samples	North Carolina, University of	J. W. Elwood
Integrated forest studies on atmospheric deposition	Norwegian Forest Research Institute	E. A. Bondietti
Lipid biochemistry of fish from East Fork Poplar Creek	Nova Scotia, University of	S. M. Adams
Preparation of chapter for DOE state-of-the- art report on global carbon cycle research	Oak Ridge Associated Universities	C. C. Coutant
Comparison of microbial communities at sites in White Oak Creek	Oak Ridge Associated Universities	A. V. Palumbo
Technical support in the conduct of aquatic bioassays	Oak Ridge Research Institute	C. W. Gehrs
Evaluate <i>Populus</i> selection for fuel wood	Oklahoma State University	P. A. Layton
Study of linked carbon and nitrogen cycles in coniferous forests	Oregon State University	W. M. Post
National Surface Water Survey data analysis project	Oregon State University	P. Kanciruk

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Continued collection of oceanic carbonate data to verify ocean penetration of anthropogenic CO ₂	Oregon State University	C. C. Coutant
Support in study of prehistoric climate determined from modern pollen-climate relationships and fossil pollen records	Oregon, University of	A. M. Solomon
Net energy and economic analysis for producing <i>Populus</i> hybrid under four management strategies	Pennsylvania State University	J. W. Ranney
Nutrient cycling research at Whiteface Mountain	Pennsylvania, University of	E. A. Bondietti
Compiling data base to test effects of toxic pollutants on marine resources	Pennsylvania, University of	L. W. Barnthouse
Extending systems analysis in ecology in Brazil	Pennsylvania, University of	D. C. West
Tissue culture of elite biotypes of <i>Atriplex canescens</i> as a short-rotation woody biomass crop	Plant Resources Institute	L. L. Wright
Development of a three-dimensional model for predicting the distribution of dissolved carbon species in the oceans	Princeton University	C. C. Coutant
The role of tropical forests in the global carbon cycle	Puerto Rico, University of	C. C. Coutant
Evaluation of the agronomic and economic feasibility of different systems for producing herbaceous biomass on marginal lands	Purdue University	J. W. Johnston
Obtain field verification of research concepts on combining scale, instrumentation, and stochastics in transport modeling of water and solutes	Purdue University	K. W. Watson

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Analyze tree-ring data to detect forest responses to increased atmospheric carbon dioxide	San Diego State University	D. C. West
Support services in the analysis of acidic deposition	Science Applications International Corporation	D. S. Shriner
Development, implementation, and analysis of models used to forecast the fate and effects of chemical contaminants in aquatic systems	Science Applications International Corporation	S. M. Bartell
Support for development, testing, and application of terrestrial ecosystem models	Science Applications International Corporation	W. R. Emanuel
Provide control of incoming analyses (status of sample analyses and detection of errors) as well as available access to existing data and associated statistical analyses	Science Applications International Corporation	P. Kanciruk
Programming and technical support for development, implementation, and analysis of uncertainties of models used to forecast future rates of fossil fuel combustion	Science Applications International Corporation	M. J. Sale
Provide scientific programmer to assist ESD ecologists in data management and analysis	Science Applications International Corporation	P. Kanciruk
Assist in ecological data management, data representation, and data analysis for ESD	Science Applications International Corporation	P. Kanciruk
Provide research and data analysis support to the National Acid Precipitation Assessment Program	Science Applications International Corporation	D. S. Shriner
Support services for the Woody Biomass Program at ORNL	Science Applications International Corporation	J. W. Ranney

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Identification and evaluation of legal-regulatory aspects of remedial action activities at ORNL	Science Applications International Corporation	J. T. Trabalka
Support in characterizing subsurface geology in immediate region for remedial action planning	South Carolina, University of	R. B. Dreier
Research to study the role of aragonite in the marine CO ₂ system	South Florida, University of	C. C. Coutant
Ecological effects of acidification of low-order woodland streams, with particular emphasis on the chemistry and effects of aluminum	Syracuse University	J. W. Elwood
Provide model for predicting water and contaminant transport	Tennessee Technological University	M. J. Sale
Sample collection from Camp Branch and Walker Branch Experimental Watersheds	Tennessee Valley Authority	D. W. Johnson
Analysis of macrobenthos samples from the Bear Creek watershed	Tennessee Valley Authority	J. M. Loar
Biomass harvesting and field handling	Tennessee Valley Authority	J. W. Ranney
Geophysical data acquisition and reduction services	Tennessee Valley Authority	S. H. Stow
Mercury and PCB uptake by fish	Tennessee Valley Authority	C. W. Gehrs
Development of plugging and abandonment plan for wells at the hydrofracture facility	Tennessee Valley Authority	M. J. Sale
Investigation of potential soil erosion at solid waste burial sites	Tennessee, University of	R. B. Clapp

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Short-term and exploratory programmatic needs in areas where staff capability and/or funding uncertainty preclude ORNL staff commitments	Tennessee, University of	S. E. Herbes
Staff members of the Department of Civil Engineering are to provide assistance in waste-management-related programs	Tennessee, University of	N. H. Cutshall
Stream acidification effects	Tennessee, University of	J. E. Elwood
Provide technical assistance in conducting DOE-sponsored limnological research on watershed-reservoir interactions	Tennessee, University of	B. L. Kimmel
A cooperative venture between ORNL's ESD and the University of Tennessee Graduate Program in Geological Sciences	Tennessee, University of	S. H. Stow
Field collection of data and sediments from lakes and ponds in Tennessee adjacent to Kentucky	Tennessee, University of	D. C. West
Support in ESD biomass project on optimum nutrition	Tennessee, University of	R. J. Luxmoore
Life Sciences Distinguished Scientist David White	Tennessee, University of	D. E. Reichle
Life Sciences Distinguished Scientist Robert Hatcher	Tennessee, University of	D. E. Reichle
Support for ESD subsurface transport project	Tennessee, University of	R. J. Luxmoore
Investigation of soil characteristics of Bear Creek Valley	Tennessee, University of	S. Y. Lee
Integrated forest study on effects of atmospheric deposition—Tasks A1 and A3	Tennessee, University of	S. E. Lindberg
Extending systems analysis in ecology	Texas A & I University	R. I. Van Hook

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Supportive research for development of plant tissue culture techniques	Texas A & M Research Foundation	J. W. Johnston
Analysis of current Biomass Production Program at ORNL	Tufts University	R. I. Van Hook
Strengthen programs in biomass and carbon dioxide research at Tuskegee Institute and Environmental Sciences Division at ORNL	Tuskegee Institute	J. H. Cushman
Establishment of <i>Populus</i> energy farms	U. S. Department of Agriculture	J. W. Ranney
Effects of atmospheric deposition on canopy and soil processes	U. S. Department of the Interior	E. A. Bondietti
Eucalyptus plantations for energy production in Hawaii	U. S. Department of Agriculture	J. W. Ranney
Research on atmospheric deposition	U. S. Department of Agriculture	E. A. Bondietti
Oilseed crops for diesel fuel substitutes	U. S. Department of Agriculture	J. H. Cushman
Precipitation data processing assistance	U. S. Department of Agriculture	D. W. Johnson
Identify risks of cultural treatments, coppice productivity, and improved productivity for energy through genetic research and selection	U. S. Department of Agriculture	J. W. Ranney
ORNL access to water quality and quantity data	U. S. Department of the Interior	S. G. Hildebrand
Evaluation of effectiveness of mitigation measures for potential loss of out-migrating anadromous fish at small-scale hydroelectric sites	U. S. Department of the Interior	S. G. Hildebrand
Increasing the biomass production of alder plantations in the Pacific Northwest	U. S. Department of Agriculture	J. W. Ranney

**9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT
SUBCONTRACTS AND INTERAGENCY AGREEMENTS (continued)**

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Continued access to the Environmental Protection Agency's STORET/BIOSTORET data base	U. S. Environmental Protection Agency	C. T. Hunsaker
Support for investigation of bedload transport of contaminated gravel in White Oak Creek drainage	Utah, University of	D. D. Huff
Production of biomass on abandoned farmlands in the Northeast	Vermont, University of	J. L. Trimble
Conduct research on the selection of lignocellulosic species for energy crops	Virginia Polytechnic Institute	J. W. Johnston
Research on production of woody biomass for fuels and chemicals in south-central Virginia	Virginia State University	L. L. Wright
Preparation and nursery establishment for study of varying physiological processes in Biomass Production Program	Washington, University of	J. W. Ranney
Effects of acid rain on forest nutrient status	Washington, University of	E. A. Bondietti
Reduce the variability in carbon isotope data from tree rings by considering the tree's physiology	Washington, University of	C. C. Coutant
Evaluation and genetic improvement of black cottonwood for short-rotation coppice culture	Washington, University of	L. L. Wright
Qualitative histopathologic examination of fish from East Fork Poplar Creek	West Virginia University	S. M. Adams
Environmental compliance audits at TAC installations	Weston, Roy F., Inc.	L. L. Sigal
Collaboratively test the HARM II site rating methods on DOE-sponsored sites	Weston, Roy F., Inc.	L. W. Barnthouse
Reconstruction of early twentieth century atmospheric CO ₂ concentrations by analyses of stored sea water samples	Woods Hole Oceanographic Institution	J. R. Trabalka
Analysis of carbonate fracture-filling and host-rock minerals	Yale University	C. S. Haase

10. CONFERENCES ORGANIZED OR CHAIRED

Preconference Workshop—Biomonitoring: Testing and Compliance Procedures for NPDES Permits, 58th Annual Water Pollution Control Federation Conference, Kansas City, Missouri, October 6, 1985. Chairman: C. T. Hunsaker.

Field Training Workshop for the National Stream Survey, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 3–7, 1986. Chairman: M. J. Sale.

Short Rotation Woody Crops Program: Annual Technical Review, Newport, Tennessee, March 17–21, 1986. Chairman: P. A. Layton.

Experimental Design and Data Management Workshop for the EPA Forest Response Program, Raleigh, North Carolina, March 25–26, 1986. Cochairmen: C. F. Baes III and R. J. Olson.

NAPAP Workshop on Dry Deposition, Harpers Ferry, West Virginia, March 25–27, 1986. Cochairmen: B. B. Hicks, S. E. Lindberg, and M. L. Wesely.

18th Annual Air Pollution Workshop, Chicago, Illinois, April 15–17, 1986. Cochairmen and organizers: L. L. Sigal and R. W. Ferenbaugh.

Direct-Delayed Response Project Data Management-Verification-Validation Workshop, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 29–31 and August 27–29, 1986. Chairman: R. S. Turner.

Herbaceous Energy Crops Program at the Annual Subcontractors' Meeting, Richmond, Virginia, August 6–7, 1986. Chairman: J. H. Cushman.

Short Rotation Woody Crops Program at the Annual Subcontractors' Meeting, Ames, Iowa, August 11–14, 1986. Chairman: P. A. Layton.

Direct-Delayed Response Project Watershed Data Aggregation Workshop, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September 8–10, 1986. Chairman: R. S. Turner.

11. SCIENTIFIC GUESTS

Environmental Sciences Division staff members routinely interact with scientists from universities, foreign institutes, government agencies, and industry. These scientific guests, who worked in the Division on a full-time or intermittent basis, are listed in Table 11.1.

**Table 11.1 Scientific guests,
October 1, 1985–September 30, 1986**

Institution	Number of guests
University/college	
University of Tennessee	
Professor	3
Associate Professor	8
Research Assistant	7
Distinguished Scientist	2
Postdoctoral Associate	1
Chemist	5
Other	6
Subtotal	32
Carleton College	
Professor	1
Indiana University	
Associate Professor	1
Dabney S. Lancaster Community College	
Professor	1
Millsaps College	
Professor	1
North Texas State University	
Assistant Professor	1
University of Arkansas	
Professor	1
University of California	
Technical Associate	1
University of Georgia	
Professor	1
University of Hawaii	
Professor	1

Table 11.1. (continued)

Institution	Number of guests
University of Illinois Professor	1
University of Kentucky Professor	1
Adjunct Associate Professor	1
University of New Mexico Professor	1
Visiting Associate Professor	1
University of Utah Professor	1
Assistant Professor	1
University of Virginia Professor	1
University of Wisconsin Professor	1
Virginia Polytechnic Institute Postdoctoral Associate	1
Foreign	
Aristotle University of Thessaloniki	1
Bhabha Atomic Research Centre	1
Commonwealth Scientific and Industrial Research Organisation	1
Forschungskommision der Universitat Zurich	1
Instituto de Radioprotecao e Dosimetria	1
Japan Atomic Energy Research Institute	1
Government	
U.S. Environmental Protection Agency	1
National Park Service	2
Tennessee Valley Authority	9
U.S. Geological Survey	3

Table 11.1. (continued)

Institution	Number of guests
Industry	
A. L. Clark Well Drilling Service	5
Environmental Consulting Engineers	1
Environmental and Social Systems Analysts	1
Geraghty and Miller	3
J. T. Bradbury	1
Lockheed Corporation	34
Maxima Corporation	3
M. L. Parker Company	1
Northrup Services, Inc.	1
Oak Ridge Research Institute	5
Planning, Design, and Research Engineers, Inc.	3
Scientific Applications International Corporation	1
Total	131

12. VISITORS (TOURS AND REGISTERED GUESTS)

During FY 1986, a total of 1387 persons toured the Environmental Sciences Division facilities (see Table 12.1). In addition to these touring groups, there were 1258 registered visitors during this period.

**Table 12.1. Environmental Sciences Division tours
October 1, 1985–September 30, 1986**

Institution ^a	Date	Number in tour
Martin Marietta Energy Systems procurement secretaries	10/10/85	6
Middle Tennessee State University	11/1/85	12
University of Tennessee Management Training Program	11/5/85	3
New employee orientation	11/12/85	20
Tennessee Technological University	11/13/85	17
Executive Seminar Center	11/18/85	30
Karns High School	11/20/85	100
Huntingdon College	11/22/85	8
Eastern Kentucky University	12/6/85	15
Southern College and University Union	1/6/86	9
ORAU minimester course	1/15/85	35
ORAU minimester course	1/16/85	35
Emory and Henry College	1/29/85	20
New employee orientation	2/11/85	18
Ferrum College	2/13/86	24
Junior Science and Humanities Symposium	2/28/85	22
Rossville Academy	3/14/85	10
University of North Carolina, Charlotte	3/18/86	15
ORAU/University of South Carolina	3/21/86	7
Executive Seminar Center	3/25/86	61
Air National Guard	4/2/86	82
Furman University	4/3/86	8
Metter High School	4/4/86	30
Belgium government official	4/10/86	1
Middle Tennessee State University	4/11/86	13
Oak Ridge High School	4/17/86	75
New employee orientation	4/21/86	25
ORAU/Dabney Lancaster College	4/22/86	9
ESD Information Meeting	5/7/86	4

Table 12.1. (continued)

Institution ^a	Date	Number in tour
Tennessee Valley Personnel Association	5/13/86	100
Air National Guard	5/15/86	83
Middle Tennessee State University	5/22/86	12
ORAU/Chipola College	6/3/86	16
ORAU/Historically Black Colleges	6/5/86	15
ORAU/Indiana University	6/18/86	12
Southern Forest Biomass Workshop	6/18/86	60
University of Tennessee Governor's School for the Sciences	6/25/86	40
Charlotte, North Carolina, High School	6/27/86	10
University of Tennessee Governor's School for the Sciences	7/2/86	18
ORNL summer employees	7/9/86	25
New employee orientation tour	7/15/86	20
New employee orientation	8/6/86	30
ORAU summer students	8/7/86	12
Air National Guard	8/13/86	81
Texas Power and Light Company	8/14/86	4
GLCA science semester students	9/3/86	26
Administrative support staff	9/11/86	25
Executive Seminar Center	9/15/86	50
Administrative support staff	9/18/86	20
Middle Tennessee State University	9/26/86	14
Total		1387

^aGLCA = Great Lakes Colleges Association; ORAU = Oak Ridge Associated Universities; ORNL = Oak Ridge National Laboratory.

13. TECHNOLOGY TRANSFER

V. S. Tripathi

Direct Transfer of Technology

Some of the technologies developed in the Environmental Sciences Division (ESD) in the course of its research activities have been transferred directly to other users:

Description: Underwater telemetry—use of ultrasonic and/or radio-frequency transmitters for attachment to fish or other aquatic organisms. Of use in animal behavior studies related to environmental impacts of aquatic resource projects such as hydropower, thermal electric generating stations, etc. ESD continues to be a center for information on the subject even though our temperature-sensing transmitter (developed by ORNL's Instrumentation and Controls Division) is now commercialized.

Researcher: C. C. Coutant

Transferred to: Numerous researchers

Source of funding: U. S. Department of Energy

* * * * *

Description: Calibration of a portable surveillance photon detector was accomplished by inserting the detector inside a lead annulus mounted on a tripod 1 m above the ground. A novel scheme using point sources of known photon intensity was devised to calibrate the detector. Units of radioactivity are expressed in either pCi/cm² or pCi/g.

Researchers: N. H. Cutshall and I. L. Larsen

Transferred to: Joseph D. Eddlemon, President, Pulcir Inc., Oak Ridge, Tennessee (a vendor of nuclear instrumentation)

Source of funding: U. S. Department of Energy, Office of Health and Environmental Research

* * * * *

Description: Methods for measurement of atmospheric deposition of coarse particles by wet and dry processes under field conditions. Used to estimate the effect of resuspended mine tailings deposited in nearby forests.

Researcher: S. E. Lindberg

Transferred to: State of Wisconsin, Department of Natural Resources, Dr. T. Hunt, Bureau of Solid Waste Management

Source of funding: U. S. Department of Energy, Electric Power Research Institute

* * * * *

Description: A synthesis of information on the evidence for regional-scale forest declines and their relationship to air pollution was provided in the form of an invited written and orally presented critical review to the Air Pollution Control Association. Scientific and political perspectives were reviewed in the light of current evidence and hypotheses.

Researcher: S. B. McLaughlin, Jr.

Transferred to: Scientists and policy makers involved in assessing pollution effects and mitigation strategies

Source of funding: U. S. Environmental Protection Agency

Indirect Transfer of Technology

The work of the Environmental Sciences Division results in technical reports or papers published in scientific journals. Many of these publications are widely read, and the information reported is used by others in their work. This, in effect, is indirect transfer of technology. Following is a list of the papers and reports that have elicited the greatest response from the scientific and industrial community in the past few years.

- Coutant, C. C. Thermal niches of striped bass. *Sci. Am.* 255(2): 98-104 (1986).
- Cutshall, N. H., I. L. Larsen, and C. R. Olsen. Direct analysis of ^{210}Pb in sediment samples: Self-absorption corrections. *Nucl. Instrum. Methods* 206:309-312 (1983).
- Lindberg, S. E., G. M. Lovett, D. D. Richter, and D. W. Johnson. Atmospheric deposition and canopy interactions of major ions in a forest. *Science* 231:141-145 (1986).
- Lindberg, S. E., and G. M. Lovett. Field measurements of particle dry deposition rates to foliage and inert surfaces in a forest canopy. *Environ. Sci. Technol.* 19:238-244 (1985).
- Luxmoore, R. J., E. G. O'Neill, J. M. Ells, and H. H. Rogers. Nutrient uptake and growth responses of Virginia pine to elevated atmospheric CO_2 . *J. Environ. Qual.* 15:244-251 (1986).
- McLaughlin, S. B. Effects of air pollution on forests: A critical review. *J. Air Pollut. Control Assoc.* 35:512-534 (1985).
- Suter, G. W., II, D. S. Vaughan, and R. H. Gardner. Risk assessment by analysis of extrapolation error: A demonstration for effects of pollutants on fish. *Environ. Toxicol. Chem.* 2:369-378 (1983).
- Yeh, G. T. Comparison of successive iteration and direct methods to solve finite element equations of aquifer contaminant transport. *Water Resour. Res.* 21(3):272-280 (1985).
- Yeh, G. T., and D. S. Ward. FEMWATER: A Finite Element Model of Water Flow Through Saturated-Unsaturated Porous Media. ORNL-5567. Oak Ridge National Laboratory, 1980.
- Yeh, G. T., and D. S. Ward. FEMWASTE: A Finite Element Model of Waste Transport Through Saturated-Unsaturated Porous Media. ORNL-5601. Oak Ridge National Laboratory, 1981.

PART IV. APPENDICES

PUBLICATIONS, PRESENTATIONS, THESES, AND PROFESSIONAL ACTIVITIES

Publications

- Adams, H. S., S. L. Stephenson, T. J. Blasing, and D. N. Duvick. 1985. Growth-trend declines of spruce and fir in mid-Appalachian subalpine forests. *Exp. Bot.* 25:315-325.
- Adams, S. M., and J. E. Breck. Bioenergetics. Chapter 12. IN C. E. Shreck and D. B. Moyle (eds.), *Methods for Fish Biology*. American Fisheries Society, Bethesda, Maryland (in press).
- Adams, S. M., C. A. Burtis, and J. J. Beauchamp. 1985. Integrated and individual biochemical responses of rainbow trout (*Salmo gairdneri*) to varying durations of acidification stress. *Comp. Biochem. Physiol.* 82C:301-310.
- Adams, S. M., and D. L. DeAngelis. Indirect effects of early bass-shad interactions on predator population structure and food web dynamics. IN W. C. Kergood (ed.), *Predation in Aquatic Communities*. University Press of New England, Hanover, New Hampshire (in press).
- Ashwood, T. L., and J. L. Gittleman. Behavioral and ecological factors influencing population density in Cheetah (*Acinonyx jubatus*): A critical review. *Biol. Conserv.* (in press).
- Ashwood, T. L., C. R. Olsen, I. L. Larsen, and P. D. Lowry. 1986. Sediment contamination in streams surrounding the Oak Ridge Gaseous Diffusion Plant. ORNL/TM-9791.
- Ashwood, T. L., C. R. Olsen, I. L. Larsen, and T. Tamura. 1986. Trace metal levels in sediments of Pearl Harbor (Hawaii). ORNL/TM-10149.
- Auerbach, S. I. Comparative forest ecosystem behavior of three long-lived radionuclides. IN Proc., Seminar on the Cycling of Long-Lived Radionuclides in the Biosphere: Observations and Models. Commission of the European Communities, Brussels (in press).
- Auerbach, S. I., and D. E. Reichle. 1986. Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1985. ORNL-6253.
- Baes, C. F., A. Bjorkstrom, and P. J. Mulholland. 1985. Uptake of carbon dioxide by the oceans. pp. 83-111. IN *Atmospheric Carbon Dioxide and the Global Carbon Cycle*. DOE/ER-0239. U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tennessee.
- Baes, C. F., III, C. T. Garten, Jr., F. G. Taylor, and J. P. Witherspoon. Long-term environmental problems of radioactively contaminated land. *Environ. Int.* 12 (in press).
- Baes, C. F., III, and S. B. McLaughlin 1986. Multielement analysis of tree rings: A survey of coniferous trees in the Great Smoky Mountains National Park. ORNL-6155.
- Baes, C. F., III, S. B. McLaughlin, and H. S. Adams. 1986. Recent investigations of growth and chemistry of tree rings in the Great Smoky Mountains National Park. pp. 28-29. IN Proc., 2nd Annual Acid Rain Conference for the Southern Appalachians. TVA/ONRED/AWR-86/11. Tennessee Valley Authority, Chattanooga, Tennessee.

- Baes, C. F., III, R. J. Olson, and K. Ritters. 1986. Quality assurance methods manual for experimental design and data management. U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, Oregon.
- Baes, C. F., III, R. W. Shor, R. C. Sharp, and A. L. Sjoeren. 1985. Two agricultural production data libraries for risk assessment models. *J. Environ. Qual.* 14:509-516.
- Barnthouse, L. W. 1986. The theory and practice of environmental impact assessment (book review). *BioScience* 36:389-390.
- Barnthouse, L. W., J. E. Breck, T. D. Jones, S. R. Kraemer, E. D. Smith, and G. W. Suter II. 1986. Development and demonstration of a hazard assessment rating methodology for Phase II of the Installation Restoration Program. ORNL/TM-9857.
- Barnthouse, L. W., and A. V. Palumbo. Assessing the transport and fate of bioengineered microorganisms in the environment. IN V. T. Covello and J. R. Fiksell (eds.), *The Suitability and Applicability of Risk Assessment Methods for Environmental Applications of Biotechnology*. Pergamon Press, New York (in press).
- Barnthouse, L. W., G. W. Suter II, S. M. Bartell, J. J. Beauchamp, R. H. Gardner, E. Linder, R. V. O'Neill, and A. E. Rosen. 1986. User's manual for ecological risk assessment. ORNL-6251.
- Bartell, S. M., R. H. Gardner, and R. V. O'Neill. 1986. The influence of bias and variance in predicting the effects of phenolic compounds in ponds. pp. 173-176. IN B. T. Fairchild (ed.), *Simulators III: Supplementary Proceedings for the 1986 Eastern Simulation Conference: Simulation at the Frontiers of Science*. Simulation Councils, Inc., San Diego, California.
- Blasing, T. J. 1985. Background: Carbon cycle, vegetation and climate responses. pp. 9-22. IN *Characterization of Information Requirements for Studies of CO₂ Effects: Water Resources, Agriculture, Fisheries, Forests, and Human Health*. DOE/ER-0236. U.S. Department of Energy, Oak Ridge Operations, Oak Ridge, Tennessee.
- Blasing, T. J. 1986. Paleoclimate analysis and modeling (book review). *Bull. Am. Meteorol. Soc.* 67:200-201.
- Blasing, T. J., and A. M. Solomon. 1986. Response of the North American corn belt to climatic warming. pp. 339-366. IN *Future Atmospheric Carbon Dioxide Scenarios and Limitation Strategies*. Noyes Publ., Park Ridge, New Jersey.
- Blasing, T. J., A. M. Solomon, and D. N. Duwick. 1985. Response functions revisited. *Tree-Ring Bull.* 44:1-15.
- Blaylock, B. G. Cycling of technetium in freshwater environments. *J. Environ. Radioact.* (in press).
- Blaylock, R. G., M. L. Frank, F. O. Hoffman, and D. L. DeAngelis. 1986. Behavior of technetium in freshwater environments. pp. 79-89. IN G. Desmet and C. Myttenaere (eds.), *Technetium in the Environment*. Elsevier Applied Science Publishers, London.
- Blaylock, B. G., F. O. Hoffman, and M. L. Frank. Tritium in the aquatic environment. IN *Proc., Commission of the European Communities Workshop on Environmental and Human Risks of Tritium*. Karlsruhe, Federal Republic of Germany (in press).

- Boegly, W. J., Jr. 1985. Experiences with dual distribution systems. pp. 5-15. IN Proc., American Water Works Association (AWWA) Seminar on Dual Water Systems (No. 20189). AWWA, Denver, Colorado.
- Boegly, W. J., Jr., and H. J. Alexander. 1986. Radioactive wastes. *J. Water Pollut. Control Fed.* 58(6):594-600.
- Boegly, W. J., Jr., R. B. Dreier, D. D. Huff, A. D. Kelmers, D. C. Kocher, S. Y. Lee, F. R. O'Donnell, F. G. Pin, and E. D. Smith. 1985. Characterization plan for Solid Waste Storage Area 6. ORNL/TM-9877.
- Boegly, W. J., Jr., C. W. Francis, and J. S. Watson. 1986. Characterization and disposal of by-product elemental sulfur. ORNL/TM-9946.
- Bogle, M. A. 1986. Continuous, remote monitoring of pH and stage in streams. pp. 102-119. IN *Ecological Effects of Acidification on Low-Order Woodland Streams, with Particular Emphasis on the Chemistry and Effects of Aluminum*. Annual Progress Report to the Electric Power Research Institute for the Period September 1984 to August 1985. EPRI, Palo Alto, California.
- Bogle, M. A. A new species of *Cladocarpus* (Coelenterata:Hydroidea:Plumulariidae) from the Straits of Florida. *Proc. Biol. Soc. Wash.* (in press).
- Bogle, M. A., R. R. Turner, and C. F. Baes III. Lead in vegetation, forest floor, and soils of the GSMNP. *Environ. Int.* (in press).
- Bondietti, E. A. 1986. The Integrated Forest Study on Effects of Atmospheric Deposition. Testimony to the Committee on Agriculture, Subcommittee on Forests, Family Farms, and Energy. United States House of Representatives, May 6, 1986. U.S. Congressional Records, Serial No. 99-27. U.S. Government Printing Office, Washington, D.C.
- Bondietti, E. A., and J. N. Brantley. 1986. Characteristics of Chernobyl radioactivity in Tennessee USA. *Nature* 322:313-314.
- Bondietti, E. A., C. Papastefanou, and C. Rangarajan. Aerodynamic size associations of natural radioactivity with ambient aerosols. *Proc., American Chemical Society Symposium, Volume on Radon*. American Chemical Society, Washington, D.C. (in press).
- Bräker, O. V., S. B. McLaughlin, and C. F. Baes III. 1986. Trace element analysis of wood, a tool for monitoring air pollution? pp. 283-285. IN *Inventorying and Monitoring Endangered Forests*. International Union of Forest Research Organisations, Zurich, Switzerland.
- Breck, J. E. 1985. Comment on "Fish/sediment concentration ratios for organic compounds." *Environ. Sci. Technol.* 19:198-199.
- Breck, J. E., D. L. DeAngelis, and W. Van Winkle. 1986. Simulating fish exposure to toxicants in a heterogeneous body of water. pp. 451-455. IN R. Crosbie and P. Luker (eds.), *Proc., 1986 Summer Computer Simulation Conference*. Society for Computer Simulation, San Diego, California.
- Cada, G. F., and R. B. McLean. 1985. An approach for assessing the impacts on fisheries of basin-wide hydropower development. pp. 367-372. IN *Proc., Symposium on Small Hydropower and Fisheries*. American Fisheries Society, Bethesda, Maryland.

- Cale, W. G., and R. V. O'Neill. Consistent models of resource competition. *Ecol. Modell.* (in press).
- Clapp, R. B., and S. E. Herbes. Research plan for investigating radionuclide migration at the West Valley Facility disposal area. Letter Report to NRC. ORNL/TM-9911 (in press).
- Clapp, R. B., C. B. Sherwood, and R. B. Dreier. 1986. Resources Management Plan for the Oak Ridge Reservation (ORR), Vol. 19: Synoptic Inventory of Groundwater Wells and Databases for the ORR. ORNL/ESH-1/V19.
- Cook, R. B., and J. S. Kahl. Water chemistry quality assurance for the Paleoecological Investigation of Recent Lake Acidification (PIRLA) project. Unpublished report series. Indiana University, Bloomington (in press).
- Cook, R. B., C. A. Kelley, D. W. Schindler, and M. A. Turner. 1986. Mechanisms of hydrogen ion neutralization in an experimentally acidified lake. *Limnol. Oceanogr.* 31:134-148.
- Cook, R. B., and C. A. Kelley. Chemical limnology of PIRLA lakes in the northern Great Lakes States. Chapter 8. IN D. F. Charles and D. R. Whitehead (eds.), *Paleoecological Investigation of Recent Lake Acidification: Project Description and Methods*. Electric Power Research Institute Interim Report. EPRI, Palo Alto, California (in press).
- Coutant, C. C. 1986. Thermal niches of striped bass. *Sci. Am.* 254:98-104.
- Coutant, C. C. Poor reproductive success of striped bass due to summer habitat limitations? *Trans. Am. Fish. Soc.* (in press).
- Coutant, C. C. Thermal preference: When does an asset become a liability? *Environ. Biol. Fishes* (in press).
- Cushman, J. H., R. F. Turhollow, and J. W. Johnston. 1986. Herbaceous Energy Crops Program: Annual Progress Report for 1985. ORNL-6263.
- Cushman, R. M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. *N. Am. J. Fish Manage.* 5:330-339.
- Cushman, R. M., P. J. Franco, J. C. Goyert, and P. A. Lesslie. 1986. Production ecology of invertebrates in small experimental ponds. *J. Tenn. Acad. Sci.* 61:80-84.
- Cutshall, N. H., and I. L. Larsen. 1986. Calibration of a portable intrinsic Ge gamma-ray detector using point sources and testing for field application. *Health Phys.* 51:53-59.
- Cutshall, N. H., I. L. Larsen, C. R. Olsen, C. A. Nittrouer, and D. J. DeMaster. 1986. Columbia River sediment in Quinault Canyon, Washington: Evidence from artificial radionuclides. *Mar. Geol.* 71:125-136.
- Dale, V. H. 1985. Testing growth-decline hypotheses using a model of forest development (abstract). p. 27. IN *Proc., 2nd Annual Acid Rain Conference for the Southern Appalachians*. Office of Natural Resources and Economic Development, Tennessee Valley Authority, Knoxville, Tennessee.
- Dale, V. H., T. W. Doyle, and H. H. Shugart. 1985. A comparison of tree growth models. *Ecol. Modell.* 29:145-169.

- Dale, V., M. Hemstrom, and J. Franklin. 1986. Modeling the long-term effects of disturbances on forest succession, Olympic Peninsula, Washington. *Can. J. For. Res.* 16:56-67.
- Davis, E. C., D. S. Marshall, R. G. Stansfield, and R. B. Dreier. 1986. ORNL Solid Waste Storage Area 6 trench photos and geologic descriptions: July 1984 through September 1985. ORNL/TM-9874.
- Davis, E. C., D. S. Marshall, R. A. Todd, and P. M. Craig. 1986. EPICOR-II: A field leaching test of radioactively loaded ion exchange resin. ORNL/TM-9850.
- Davis, E. C., and R. R. Shoun. Environmental data package for ORNL Solid Waste Storage Area 4, the adjacent intermediate-activity low-level liquid waste transfer line, and the liquid waste pilot pit area. ORNL/TM-10155 (in press).
- Davis, E. C., and B. P. Spalding. 1986. Field evaluation of a cement-bentonite grout and a chloro-sulfonated polyethylene fabric liner in hydrologically isolating low-level radioactive solid waste. ORNL/TM-9742.
- Davis, E. C., R. G. Stansfield, L. A. Melroy, and D. D. Huff. 1985. Water diversion at low-level waste disposal sites. *J. Environ. Eng. Div. ASCE* 111(5):714-729.
- DeAngelis, D. L., and M. A. Huston. Effects of growth rates in models of size distribution formation in plants and animals. *Ecol. Modell.* (in press).
- DeAngelis, D. L., J. A. Kitchell, and W. M. Post. 1985. The influence of naticid predation on evolutionary strategies of bivalve prey: Conclusions from a model. *Am. Nat.* 126:817-842.
- DeAngelis, D. L., W. M. Post, and C. C. Travis. 1986. *Positive Feedback in Natural Systems*. Springer-Verlag, Berlin.
- DeAngelis, D. L., and J. C. Waterhouse. Equilibrium and nonequilibrium concepts in ecological modeling. *Ecology* (in press).
- DeAngelis, D. L., J. C. Waterhouse, W. M. Post, and R. V. O'Neill. 1985. Ecological modelling and disturbance evaluation. *Ecol. Modell.* 29:399-419.
- Edwards, N. T. 1986. Uptake, translocation, and metabolism of anthracene by bush beans (*Phaseolus vulgaris* L.). *Environ. Toxicol. Chem.* 5:659-665.
- Edwards, N. T. Assimilation and metabolism of polycyclic aromatic hydrocarbons by vegetation: An approach to this controversial issue and suggestions for future research. IN M. Cooke and A. J. Dennis (eds.), *Polynuclear Aromatic Hydrocarbons, Proc., 10th Anniversary International Symposium*. Battelle Press, Columbus, Ohio.
- Edwards, N. T., D. W. Johnson, S. B. McLaughlin, and W. F. Harris. Carbon dynamics and productivity. Chapter 6. IN D. W. Johnson and R. I. Van Hook (eds.), *Analysis of Forested Watershed Processes*. Springer-Verlag, New York (in press).
- Elwood, J. W., M. A. Bogle, H. L. Boston, E. B. Cook, C. T. Driscoll, P. J. Mulholland, A. V. Palumbo, A. D. Rosemond, C. L. Schofield, and R. R. Turner. 1986. Ecological Effects of Acidification on Low-Order Woodland Streams, with Particular Emphasis on the Chemistry and Effects of Aluminum. Annual Progress Report to the Electric Power Research Institute for the Period September 1984 to August 1985. EPRI, Palo Alto, California.

- Elwood, J. W., and R. R. Turner. 1986. Streams: Water chemistry and ecology. Chapter 8. IN D. W. Johnson and R. I. Van Hook (eds.), *Analysis of Forested Watershed Processes*. Springer-Verlag, New York (in press).
- Emanuel, W. R., Y.-S. Fung, G. G. Killough, B. Moore, and T.-H. Peng. 1985. Modeling the global carbon cycle and changes in the atmospheric carbon dioxide levels. pp. 141-173. IN J. R. Trabalka (ed.), *Atmospheric Carbon Dioxide and the Global Carbon Cycle*. DOE/ER-0239. Carbon Dioxide Research Division, U.S. Department of Energy, Washington, D.C.
- Emanuel, W. R., H. H. Shugart, and M. P. Stevenson. 1985. Response to comment: Climatic change and the broad-scale distribution of terrestrial ecosystem complexes. *Clim. Change* 7:457-460.
- Emanuel, W. R., M. P. Stevenson, and H. H. Shugart. Global response of vegetation to climate change. IN B. Bolin (ed.), *CO₂ and Climate Change Assessment*. John Wiley, New York (in press).
- Francis, C. W., E. C. Davis, and J. C. Goyert. 1985. Plant uptake of heavy metals from coal gasification ashes. *J. Environ. Qual.* 14:561-569.
- Francis, C. W., and M. P. Maskarinec. 1986. Field and laboratory studies in support of a hazardous waste extraction test. ORNL-6247.
- Francis, C. W., M. P. Maskarinec, and J. C. Goyert. 1985. A laboratory extraction method to simulate codisposal of solid waste in municipal waste landfills. pp. 15-35. IN J. K. Petros, Jr., W. J. Lacy, and R. A. Conway (eds.), *Hazardous and Industrial Solid Waste Testing: Fourth Symposium*. ASTM STP 886. American Society for Testing and Materials, Philadelphia.
- Francis, C. W., and R. G. Stansfield. 1986. Characterization plan for the old hydrofracture facility. ORNL/TM-9991.
- Francis, C. W., and R. G. Stansfield. 1986. Groundwater monitoring at three Oak Ridge National Laboratory inactive waste impoundments. ORNL/TM-10193.
- Garten, C. T., Jr., C. Myttenaere, C. M. Vandecasteele, R. Kirchmann, and R. Van Bruwaene. 1986. Chemical form of technetium in corn (*Zea mays*) and the gastrointestinal absorption of plant-incorporated Tc by laboratory rats. pp. 319-332. IN G. Desmet and C. Myttenaere (eds.), *Technetium in the Environment*. Elsevier Applied Science Publishers, New York.
- Garten, C. T., Jr., C. S. Tucker, and T. G. Scott. Plant uptake of neptunium-237 and technetium-99 under field conditions. *J. Environ. Radioact.* (in press).
- Garten, C. T., Jr., C. S. Tucker, and B. T. Walton. 1986. Environmental fate and distribution of technetium-99 in a deciduous forest ecosystem. *J. Environ. Radioact.* 3:163-188.
- Haase, C. S., G. A. Gillis, and H. L. King. Groundwater investigation drilling program for fiscal year 1985 at the Y-12 Facility, Oak Ridge, Tennessee. ORNL/TM-9999 (in press).
- Haase, C. S., and K. O. Hasson. 1986. Basement influence on Mississippi Valley-type mineralization in east Tennessee. pp. 168-174. IN M. J. Aldrich and A. W. Laughlin (eds.), *Proc., 6th International Conference on Basement Tectonics*. University of New Mexico Press, Albuquerque.

- Haase, C. S., and S. H. Stow. 1986. Preliminary chemical and radionuclide data from deep monitoring wells at the New Hydraulic Fracturing Facility, Oak Ridge National Laboratory. Letter Report to the U.S. Department of Energy, Washington, D.C.
- Heck, W. W., and S. B. McLaughlin. 1986. Synthesis-effects of gaseous air pollutants on vegetation. pp. 325-336. IN A. H. Legge and S. V. Krupa (eds.), *Air Pollutants and Their Effects on the Terrestrial Ecosystem*. Wiley-Interscience, New York.
- Hildebrand, S. G., L. W. Barnhouse, and G. W. Suter. The role of basic ecological knowledge in environmental assessment. IN Proc., National Science Foundation/Council on Environmental Quality (NSF/CEQ) Panel Meeting on Long-Term Environmental Research Needs, Washington, D.C. Praeger/Greenwood Publ., New York (in press).
- Hoffman, F. O., and B. G. Blaylock. 1986. Proceedings of a DOE/OHER Workshop on the Validation and Testing of Mathematical Models with Real Data Sets. BIOMOVs Newsletter No. 1:1-9 (June).
- Hoffman, F. O., and B. G. Blaylock. 1986. Issues for model validation. BIOMOVs Newsletter No. 2:8-12 (July).
- Hoffman, F. O., and B. G. Blaylock. 1986. Screening techniques for determining compliance with environmental standards: Releases of radionuclides to the atmosphere. NCRP Commentary No. 3. National Council on Radiation Protection and Measurements, Bethesda, Maryland.
- Hoffman, F. O., R. H. Gardner, and S. M. Bartell. 1986. The significance of environmental exposure pathways for technetium. pp. 359-375. IN G. Desmet and C. Myttenaere (eds.), *Technetium in the Environment*. Elsevier Applied Science Publishers, London.
- Hunsaker, C. T. 1985. Radioactivity in the ocean: Laws and biological effects. pp. 629-648. IN *Coastal Zone '85, Proc., 4th Symposium on Coastal and Ocean Management, Vol. 1*. American Society of Civil Engineers, New York.
- Hunsaker, C. T., J. L. Malanchuk, R. J. Olson, S. W. Christensen, and R. S. Turner. Adirondack headwater lake chemistry relationships with watershed characteristics. *Water Air Soil Pollut.* (in press).
- Huston, M. A. 1985. Patterns of species diversity in relation to depth at Discovery Bay, Jamaica. *Bull. Mar. Sci.* 37:928-935.
- Huston, M. A. 1986. Size bimodality in plant populations. *Ecology* 67:265-269.
- Huston, M. A., and D. L. DeAngelis. Size bimodality in monospecific populations: Potential mechanisms. *Am. Nat.* (in press).
- Huston, M. A., and T. M. Smith. Competition, life history, and plant succession. *Am. Nat.* (in press).
- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and V. S. Tripathi. 1985. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques and procedures for the month of October 1985. ORNL/NRC/LTR-85/33.

- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and W. S. Tripathi. 1985. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques and procedures for the month of November 1985. ORNL/NRC/LTR-85/34.
- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and V. S. Tripathi. 1986. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques, and procedures for the month of December 1985. ORNL/NRC/LTR-86/1.
- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and V. S. Tripathi. 1986. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques, and procedures for the month of January 1986. ORNL/NRC/LTR-86/6.
- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and V. S. Tripathi. 1986. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques and procedures for the month of February 1986. ORNL/NRC/LTR-86/8.
- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and V. S. Tripathi. 1986. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques and procedures for the month of March 1986. ORNL/NRC/LTR-86/12.
- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and V. S. Tripathi. 1986. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques and procedures for the month of April 1986. ORNL/NRC/LTR-86/13.
- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and V. S. Tripathi. 1986. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques and procedures for the month of May 1986. ORNL/NRC/LTR-86/15.
- Jacobs, G. K., W. D. Arnold, J. G. Blencoe, A. D. Kelmers, R. E. Meyer, and V. S. Tripathi. 1986. Laboratory evaluation of DOE radionuclide solubility data and selected retardation parameters, experimental strategies, laboratory techniques and procedures for the month of June 1986. ORNL/NRC/LTR-86/16.
- Johnson, A. H., and S. B. McLaughlin. 1986. The nature and timing of the deterioration of red spruce in the northern Appalachian Mountains. pp. 200-230. IN *Acid Deposition—Long-Term Trends*. National Academy Press, Washington, D.C.
- Johnson, D. W. Site description. Chapter 2. IN D. W. Johnson and R. I. Van Hook (eds.), *Analysis of Forested Watershed Processes*. Springer-Verlag, New York (in press).
- Johnson, D. W., D. W. Cole, H. Van Miegroet, and F. W. Horng. 1986. Factors affecting anion movement and retention in four forest soils. *Soil Sci. Soc. Am. J.* 50:776-783.

- Johnson, D. W., and G. S. Henderson. Terrestrial nutrient cycling. Chapter 7. IN D. W. Johnson and R. I. Van Hook (eds.), *Analysis of Forested Watershed Processes*. Springer-Verlag, New York (in press).
- Johnson, D. W., J. M. Kelly, W. T. Swank, D. W. Cole, J. W. Hornbeck, R. S. Pierce, and D. Van Lear. 1985. A comparative evaluation of the effects of acid precipitation, natural acid production, and harvesting on cation removal from forests. ORNL/TM-9706.
- Johnson, D. W., S. E. Lindberg, E. A. Bondietti, and L. F. Pitelka. 1986. The integrated forest study on effects of atmospheric deposition. Paper 2-2, pp. 3-13. IN *Proc., Annual Technical Association Pulp and Paper Industry 1986 Meeting*. TAPPI Press, Atlanta, Georgia.
- Johnson, D. W., and D. E. Todd. 1985. Nitrogen availability and conservation in young yellow-poplar and loblolly pine plantations fertilized with urea. p. 220. IN *Agronomy Abstracts*. Soil Science Society of America, Madison, Wisconsin.
- Johnson, D. W., and R. I. Van Hook (eds.). *Analysis of Forested Watershed Processes*. Springer-Verlag, New York (in press).
- Johnston, J. W., Jr., and D. S. Shriner. 1985. Responses of three wheat cultivars to simulated acid rain. *Environ. Exp. Bot.* 25:349-353.
- Johnston, J. W., Jr., and D. S. Shriner. 1986. Yield response of Davis soybeans to simulated acid rain and gaseous pollutants in the field. *New Phytol.* 103:695-707.
- Johnston, J. W., D. S. Shriner, and C. H. Abner. 1986. Design and performance of an exposure system for measuring the response of crops to acid rain and gaseous pollutants in the field. *J. Air Pollut. Control Assoc.* 36:894-899.
- Johnston, J. W., Jr., D. S. Shriner, and C. K. Kinnerly. 1986. The combined effects of simulated acid rain and ozone on injury, chlorophyll, and growth of radish. *Environ. Exp. Bot.* 26:107-113.
- Kanciruk, P., J. M. Eilers, R. A. McCord, D. H. Landers, D. F. Brakke, and R. A. Linthurst. 1986. Characteristics of Lakes in the Eastern United States, Vol. III: Data Compendium of Site Characteristics and Chemical Variables. EPA/600/4-86/007c. Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.
- Kanciruk, P., M. Gentry, R. McCord, L. Hook, J. Eilers, and M. D. Best. 1986. National Surface Water Survey, Eastern Lake Survey—Phase I: Data base dictionary. ORNL/TM-10153.
- Kanciruk, P., R. J. Olson, and R. A. McCord. 1986. Quality control in research databases: The U.S. Environmental Protection Agency National Lake Survey experience. pp. 193-207. IN W. K. Michener (ed.), *Research Data Management in the Environmental Sciences*. Belle W. Baruch Institute for Marine Biology and Coastal Research. University of South Carolina Press, Columbia, South Carolina.
- Kimmel, B. L., and A. W. Groeger. 1986. Limnological and ecological changes associated with reservoir aging. pp. 103-109. IN G. E. Hall and M. J. Van Den Avyle (eds.), *Reservoir Fisheries Management: Strategies for the 80s*. Reservoir Committee, American Fisheries Society, Bethesda, Maryland.

- Kimmel, B. L., and A. W. Groeger. 1986. Size distribution of planktonic autotrophy and microheterotrophy in Degray and West Point Reservoirs: A comparative study. Environmental and Water Quality Operational Studies Technical Report E-86-8. Environmental Laboratory, U.S. Army Engineers, Waterways Experiment Station, Vicksburg, Mississippi.
- Kimmel, B. L., and J. R. Holt. Nutrient availability and patterns of polymorphism in the freshwater dinoflagellate, *Ceratium hirundinella* (Dinophyceae). J. Phycol. (in press).
- Krom, M. D., K. K. Turekian, and N. H. Cutshall. 1985. Fate of metals in the sediments of the New York Bight. Chapter 9, pp. 209-234. IN B. Ketchum, J. Capuzzo, W. Burt, I. Duedall, P. Park, and D. Kestez (eds.), Wastes in the Ocean, Vol. 6: Nearshore Waste Disposal. John Wiley & Sons, New York.
- Krummel, J. R., R. H. Gardner, G. Sugihara, and R. V. O'Neill. Landscape patterns in a disturbed environment. Oikos (in press).
- Krummel, J. R., R. V. O'Neill, and J. B. Mankin. 1986. Regional environmental simulation of African cattle herding societies. Human Ecol. 14:117-130.
- Lee, S. Y. D. C. Kopp, and T. J. Henson. Color photograph for cover of *Geology* (Composite Elemental Mapping of Mineralogical Relationships). Geology (in press).
- Lee, S. Y., T. Tamura, I. L. Larsen, and E. H. Essington. Characteristics of radionuclide-contaminated soils from the Sedan Crater area at the Nevada Test Site. Soil Sci. (in press).
- Lindberg, S. E. 1986. Collection and analysis of trace metals in continental precipitation at forested sites in the southeastern United States. pp. 1-13. IN L. A. Barrie (ed.), Proc., Workshop on Analysis of Metals in Rain. Atmospheric Environment Service of Canada, Toronto, Canada.
- Lindberg, S. E. 1986. Mercury vapor in the atmosphere: Three case studies on emission, deposition, and plant uptake. pp. 555-560. IN J. O. Nriagu and C. I. Davidson (eds.), Metals in the Air. John Wiley, New York.
- Lindberg, S. E., R. C. Harriss, G. M. Lovett, R. R. Turner, and W. A. Hoffman. Atmospheric chemistry, deposition, and canopy interactions. Chapter 4. IN D. W. Johnson and R. I. Van Hook (eds.), Analysis of Forested Watershed Processes. Springer-Verlag (in press).
- Lindberg, S. E., and G. M. Lovett. 1985. Field measurements of particle dry deposition rates to foliage and inert surfaces in a forest canopy. Environ. Sci. Technol. 19:238-244.
- Lindberg, S. E., G. M. Lovett, D. D. Richter, and D. W. Johnson. 1986. Atmospheric deposition and canopy interaction of major ions in a forest. Science 231:141-145.
- Lindberg, S. E., and S. B. McLaughlin. 1986. Air pollutant interactions with vegetation: Research needs to data acquisition and interpretation. pp. 449-504. IN Air Pollutants and Their Effects on the Terrestrial Ecosystem. John Wiley and Sons, New York.
- Loar, J. M., M. J. Sale, and G. F. Cada. 1986. Instream flow needs to protect fishery resources. pp. 2098-2105. IN M. Karamouz, G. R. Baumli, and W. J. Brick (eds.), Proc., Water Forum '86: World Water Issue in Evolution, Vol. 2. American Society of Civil Engineers, New York.

- Luxmoore, R. J. (ed.). 1985. Coupling of Carbon, Water, and Nutrient Interactions in Woody Plant Soil Systems: Program and Presentation Summaries. International Union of Forest Research Organisations Symposium on Coupling of Carbon, Water, and Nutrient Interactions in Woody Plant Soil Systems. CONF-851050. National Technical Information Service, Springfield, Virginia.
- Luxmoore, R. J. 1985. Soil water flow characterization (abstract). EOS Trans. Am. Geophys. Union 66:267.
- Luxmoore, R. J. Modeling chemical transport, uptake, and effects in the soil-plant-litter system. Chapter 9. IN D. W. Johnson and R. I. Van Hook (eds.), Analysis of Forested Watershed Processes. Springer-Verlag, New York (in press).
- Luxmoore, R. J., and D. D. Huff. Water. Chapter 5. IN D. W. Johnson and R. I. Van Hook (eds.), Analysis of Forested Watershed Processes. Springer-Verlag, New York (in press).
- Luxmoore, R. J., R. J. Norby, and E. G. O'Neill. 1986. Seedling tree responses to nutrient stress under atmospheric CO₂ enrichment. pp. 178-183. IN 18th International Union of Forest Research Organisations World Congress. Division 2, Vol. 1. IUFRO Secretariate, Vienna, Austria.
- Luxmoore, R. J., E. G. O'Neill, J. M. Ells, and H. H. Rogers. 1986. Nutrient uptake and growth responses of Virginia pine to elevated atmospheric carbon dioxide. J. Environ. Qual. 15:244-251.
- Luxmoore, R. J., K. W. Watson, G. R. Southworth, R. R. Turner, and R. C. Ward. 1986. Macropore and soil variability effects on hydrologic transport processes. pp. 108-109. IN Transactions of the XIII Congress of the International Society of Soil Science, Vol. II. Wageningen, The Netherlands.
- Mann, L. K. 1985. A regional comparison of carbon in cultivated and uncultivated Alfisols and Mollisols in the central United States. Geoderma 36:241-253.
- Mann, L. K. 1986. Changes in soil carbon storage after cultivation. Soil Sci. 142:279-288.
- McBrayer, J. F., and D. G. Jacobs. 1985. Institutional and technical issues in the management of low-level mixed wastes. pp. 81-84. IN R. G. Post (ed.), Waste Management 85, Vol. 2. University of Arizona, Tucson.
- McCarthy, J. F., and M. C. Black. The effect of dissolved organic macromolecules on the exposure of aquatic organisms to organic contaminants. IN Proc., 10th Symposium on Aquatic Toxicology and Hazard Assessment. American Society for Testing and Materials, Philadelphia (in press).
- McCarthy, J. F., and B. D. Jimenez. 1985. Interactions between polycyclic aromatic hydrocarbons and dissolved humic materials: Binding and dissociation. Environ. Sci. Technol. 19:1072-1076.
- McCarthy, J. F., B. D. Jimenez, and T. Barbee. 1985. Effect of dissolved humic material on accumulation of polycyclic aromatic hydrocarbons: Structure-activity relationships. Aquat. Toxicol. 7:15-24.

- McLaughlin, S. B. 1986. Sulfur and nitrogen dioxide effects on forest systems—Evaluation of potential for effects and research needs. Testimony to the House Agriculture Subcommittee on Forest, Family Farms, and Energy. Congressional Record, May 13, 1986.
- McLaughlin, S. B., and T. J. Blasing. 1985. Response to comments on FORAST Projects 2A and 2B. *Am. Statist.* 39:263–265.
- McLaughlin, S. B., D. J. Downing, T. J. Blasing, B. L. Jackson, D. J. Pack, D. N. DuVick, L. K. Mann, and T. N. Doyle. 1986. FORAST data base documentation: Final draft (report to Environmental Protection Agency) ORNL/FPO-86/72.
- McLaughlin, S. B., and G. E. Taylor. 1986. SO₂ effects on dicot crops: Some issues, mechanisms, and indicators. pp. 227–249. IN W. E. Winner, H. A. Mooney, and R. A. Goldstein (eds.), *Sulfur Dioxide and Vegetation*. Stanford University Press, Stanford, California.
- Millemann, R. E., and R. M. Cushman. 1986. Carbon Dioxide Information Center Thesaurus. ORNL/CDIC-5.
- Mulholland, P. J., J. W. Elwood, A. V. Palumbo, and R. J. Stevenson. Effect of stream acidification on periphyton composition, abundance, and productivity. *Can. J. Fish. Aquat. Sci.* (in press).
- Norby, R. J., E. G. O'Neill, and R. J. Luxmoore. 1986. Effects of atmospheric CO₂ enrichment on the growth and mineral nutrition of *Quercus alba* seedlings in nutrient-poor soil. *Plant Physiol.* 82:83–89.
- Norby, R. J., J. Pastor, and J. M. Melillo. Carbon-nitrogen interactions in CO₂-enriched white oak: Physiological and long-term perspectives. *Tree Physiol.* 2 (in press).
- Norby, R. J., B. K. Takemoto, J. W. Johnston, and D. S. Shriner. 1986. Acetylene reduction rate as a physiological indicator of the response of field-grown soybeans to simulated acid rain and ambient gaseous pollutants. *Environ. Exp. Bot.* 20:285–290.
- Norby, R. J., G. E. Taylor, Jr., S. B. McLaughlin, and C. A. Gunderson. Drought sensitivity of red spruce seedlings affected by precipitation chemistry. IN *Proc., Ninth North American Forest Biology Workshop*, Stillwater, Oklahoma (in press).
- Olsen, C. R., I. L. Larsen, P. D. Lowry, N. H. Cutshall, and M. M. Nichols. 1985. Cosmogenic ⁷Be as a tracer for short-term estuarine processes (abstract). *Estuarine Research Federation Annual Meeting*. *Estuaries* 8:120.
- Olsen, C. R., I. L. Larsen, P. D. Lowry, N. H. Cutshall, and M. M. Nichols. 1986. Geochemistry and deposition of ⁷Be in river-estuarine and coastal waters. *J. Geophys. Res.—Oceans* 91:896–908.
- Olsen, C. R., I. L. Larsen, P. D. Lowry, N. H. Cutshall, J. F. Todd, and G. T. F. Wong. 1985. Atmospheric fluxes and marsh-soil inventories of ⁷Be and ²¹⁰Pb. *J. Geophys. Res.—Atmospheres* 90:10487–10495.
- Olsen, C. R., P. D. Lowry, S. Y. Lee, I. L. Larsen, and N. H. Cutshall. 1986. Geochemical and environmental processes affecting radionuclide migration from a formerly used seepage trench. *Geochim. Cosmochim. Acta* 50:593–607.

- Olson, R. J. and L. J. Allison. 1985. ADDNET Notes, No. 4, December (newsletter). ORNL/FPO-85/241.
- Olson, R. J., R. C. Durfee, and D. L. Wilson. Application of a geographic information system in the study of acidic deposition. IN Proc., Geographic Information Systems for Environmental Protection. University of Nevada, Las Vegas (in press).
- Olson, R. J., and P. Kanciruk. 1986. Locating machine-readable ecological data. pp. 125-142. IN Proc., Research Data Management in the Ecological Sciences Symposium. University of South Carolina Press, Columbia.
- Olson, R. J., and N. T. Millemann (eds.). 1985. Proc., 1983 Integrated Data Users Workshop. USGS National Center, Reston, Virginia. CONF--83117. National Technical Information Service, Springfield, Virginia.
- Olson, R. J., R. S. Turner, and L. J. Allison. 1985. Examples of regional environmental assessment using acid deposition data. pp. 358-364. IN Proc., Hazardous Wastes and Environmental Emergencies Symposium. Hazardous Materials Control Institute, Silver Springs, Maryland.
- O'Neill, R. V. Review of S. N. Salthe's "Evolving Hierarchical Systems." Environ. Manage. (in press).
- O'Neill, R. V., D. L. DeAngelis, J. B. Waide, and T. F. H. Allen. 1986. A Hierarchical Concept of Ecosystems. Princeton University Press, Princeton, New Jersey.
- Parr, P. D., and R. K. Jones. 1986. Initiation of long-term research on a rare plant population on the Oak Ridge National Environmental Research Park. IN Proc., Association of Southeast Biologists Annual Meeting. Assoc. Southeast Biol. Bull. 33:69.
- Peng, T.-H. 1985. Application of box models for geochemical modeling of oceans. Chemometrics Research Conference. J. Res. Natl. Bur. Stand. 90:530.
- Peng, T.-H. 1986. Uptake of anthropogenic CO₂ by lateral transport models of the ocean based on the distribution of bomb-produced ¹⁴C. Radiocarbon 28:363-375.
- Peng, T.-H. 1986. Comment on "Land Use Change and Carbon Exchange in the Tropics. 2. Estimates for the Entire Region." Environ. Manage. 10(5):573-575.
- Peng, T.-H., and W. S. Broecker. 1985. Pandora: An eleven-box geochemical model of the world ocean. pp. 113-118. IN Report on the Carbon Transfer Conference. Scripps Institution of Oceanography.
- Peng, T.-H., and H. D. Freyer. 1986. Revised estimates of atmospheric CO₂ variations based on tree-ring ¹³C record. pp. 151-159. IN J. R. Trabalka and D. E. Reichle (eds.), The Changing Carbon Cycle: A Global Analysis. Springer-Verlag, New York.
- Peng, T.-H., and T. Takahashi. Modeling the seasonal variations of pCO₂ in the North Atlantic surface water. Tellus (in press).
- Post, W. M., D. L. DeAngelis, and P. J. Taylor. 1985. Food web assembly and ecosystem processes in reservoirs: A simulation model. ESA Bull. 66:249-250.

- Ranney, J. W. New technologies in woody crops for energy production in the United States. Chapter 7. IN Advanced Solar Energy. Solar Energy Research Institute, Golden, Colorado (in press).
- Ranney, J. W., R. D. Perlack, J. L. Trimble, and L. L. Wright. 1985. Specialized hardwood crops for energy and fiber: Status, impact, and need. TAPPI J. 68:36-41.
- Ranney, J. W., J. L. Trimble, L. L. Wright, P. A. Layton, R. D. Perlack, C. R. Wenzel, and D. T. Curtin. 1985. Short Rotation Woody Crops Program: Annual Progress Report for 1985. ORNL-6254.
- Ranney, J. W., J. L. Trimble, L. L. Wright, and R. D. Perlack. 1986. Research on short-rotation woody crops in the South. pp. 71-84. IN Biomass Energy Development. Plenum, New York.
- Reed, R. M. 1986. Environmental Compliance Program reference book: Toxic Substances Control Act, Revision 2. ORNL/M-202.
- Reed, R. M. 1986. Environmental Compliance Program reference book: Resource Conservation and Recovery Act, Revision 3. ORNL/M-237.
- Reed, R. M. 1986. Environmental Compliance Program reference book: Comprehensive Environmental Response Compensation, and Liability Act (CERCLA), Revision 4. ORNL/M-200/R4.
- Reichle, D. E., J. R. Trabalka, and A. M. Solomon. 1985. Approaches to studying the global carbon cycle. pp. 15-24. IN J. R. Trabalka (ed.), Atmospheric Carbon Dioxide and the Global Carbon Cycle. DOE/ER-0239. U.S. Government Printing Office, Washington, D.C.
- Rosen, A. E., and P. Kanciruk. 1985. A generic data entry quality assurance tool. pp. 434-436. IN Proc., 10th Annual SAS Users Group International Conference. SAS Institute, Inc., Cary, North Carolina.
- Sale, M. J., W. Van Winkle, G. F. Cada, C. C. Coutant, A. J. Witten, J. W. Elwood, and F. C. Kornegay. 1985. Integrated aquatic habitat assessment for the Susitna Hydroelectric Project, Alaska. pp. 25-31. IN Proc., Symposium on Small Hydropower and Fisheries. American Fisheries Society, Bethesda, Maryland.
- Salk, M. S., R. L. Jolley, H. W. Godbee, J. E. Mrochek, T. M. Gilliam, W. D. Box, R. B. Rodgers, T. D. Jones, T. Aldrich, and J. W. Webb. 1986. Evaluation of EPA's proposed rule—Hazardous Waste Management System: Identification and listing of hazardous waste, notification requirements, and reportable quantity adjustments (51 FR 21647-21693; 40 CFR Parts 261, 271, and 302). Prepared for the Office of Environmental Guidance, U.S. Department of Energy, Washington, D.C.
- Sharples, F. E. 1986. Regulatory Reference Book for Hazardous Waste. ORNL/M-181.
- Sharples, F. E. Human gene therapy: A look at a cutting edge of biomedical science. ORNL Rev. (in press).
- Sharples, F. E. Genetic engineering and the civil liberties of science (book review). BioScience (in press).

- Shriner, D. S., and J. W. Johnston, Jr. 1985. Acid rain interactions with leaf surfaces: A review. pp. 241-253. IN Acid Deposition. Plenum, New York.
- Shugart, H. H., and S. B. McLaughlin. 1986. Modeling SO₂ effects on forest growth and community dynamics. pp. 478-494. IN W. E. Winner, H. A. Mooney, and R. A. Goldstein (eds.), Sulfur Dioxide and Vegetation. Stanford University Press, Stanford, California.
- Shugart, L., J. McCarthy, B. Jimenez, and J. Daniels. Analysis of adduct formation in the bluegill sunfish (*Lepomis macrochirus*) between benzo[a]pyrene and DNA of the liver and hemoglobin of the erythrocyte. Aquat. Toxicol. (in press).
- Sigal, L. L., and J. W. Johnston, Jr. 1986. Effects of acidic rain and ozone on nitrogen fixation and photosynthesis in the lichen *Lobaria pulmonaria* (L.) Hoffm. Environ. Exp. Bot. 26:59-64.
- Sigal, L. L., and J. W. Johnston, Jr. 1986. Effects of simulated acidic rain on one species each of *Pseudoparmelia*, *Usnea*, and *Umbilicaria*. Water Air Soil Pollut. 27:315-322.
- Smith, E. D., L. W. Barnthouse, G. W. Suter II; J. E. Breck, T. D. Jones, and D. A. Sanders. 1986. Improving the risk relevance of systems for assessing the relative hazard of contaminated sites. pp. 336-341. Proc., 3rd National Conference on Hazardous Wastes and Hazardous Materials. Hazardous Materials Control Research Institute, Silver Springs, Maryland.
- Smith, E. D., and N. D. Vaughan. 1986. Reply to the preceding discussion by R. E. Read of "Aquifer Test Analysis in Nonradial Flow Regimes: A Case Study." Ground Water 24:91-92.
- Solomon, A. M. 1986. Transient responses of forests to CO₂-induced climate exchange: Simulation modeling experiments in eastern North America. Oecologia 68:567-579.
- Solomon, A. M. Comparison of taxon calibrations, modern analog techniques, and forest-stand simulation models for the quantitative reconstruction of past vegetation: A critique. Earth Surf. Processes Landforms (in press).
- Solomon, A. M., and A. B. Silkworth. 1986. Spatial patterns of atmospheric pollen transport in a montane region. Quat. Res. 25:150-162.
- Solomon, A. M., J. R. Trabalka, D. E. Reichle, and L. D. Voorhees. 1985. The global cycle of carbon. pp. 1-13. IN J. R. Trabalka (ed.), Atmospheric Carbon Dioxide and the Global Carbon Cycle. DOE/ER-0239. U.S. Department of Energy, Washington, D.C.
- Solomon, A. M., and D. C. West. 1985. Potential responses of forests to CO₂-induced climate change. pp. 145-169. IN M. R. White (ed.), Characterization of Information Requirements for Studies of CO₂ Effects: Water Resource, Agriculture, Fisheries, Forests and Human Health. DOE/ER-0236. U.S. Department of Energy, Washington, D.C.
- Solomon, J. A. 1985. Ultrastructure evaluation of lipid accumulation in microalgae. pp. 71-82. IN Proc., Principal Investigators' Meeting, Aquatic Species Program Review. Solar Energy Research Institute, Golden, Colorado.
- Solomon, J. A., P. L. Walne, and P. A. Kivic. *Entosiphon sulcatum*: Flagellar roots of the basal body complex and reservoir region (Euglenophyceae). J. Phycol. (in press).
- Southworth, G. R., and J. L. Keller. 1986. Hydrophobic sorption of polar organics by low organic carbon soils. Water Air Soil Pollut. 28:239-248.

- Stansfield, R. G., and C. W. Francis. 1986. Characteristics of the 3513 impoundment. ORNL/TM-9936.
- Stansfield, R. G., and C. W. Francis. 1986. Characterization of the Homogeneous Reactor Experiment No. 2 (HRE) impoundment. ORNL/TM-10002.
- Stansfield, R. G., and C. W. Francis. 1986. Characterization of the Old Hydrofracture Facility (OHF) impoundment. ORNL/TM-9990.
- Stansfield, R. G., and C. W. Francis. Characterization plan for the waste holding basin (3513 impoundment). ORNL/TM-9969 (in press).
- Stewart, A. J. Responses of stream algae to grazing minnows and nutrients: A field test for interactions. *Oecologia* (in press).
- Stewart, A. J., and R. G. Wetzel. 1986. Cryptophytes and other microflagellates as couplers in planktonic community dynamics. *Arch. Hydrobiol.* 106(1):1-19.
- Stow, S. H. 1986. The impact of recently enacted federal legislation on demand for geoscientists (abstract). p. 267. IN Geological Society of America Abstracts and Program, Southeastern Section Meeting. [Also in *Oklahoma Geology Notes* 46:(3)121-122.]
- Stow, S. H., and C. S. Haase. 1986. Subsurface disposal of liquid low-level radioactive wastes at Oak Ridge, Tennessee. pp. 656-675. *Proc., International Symposium on Subsurface Injection of Liquid Wastes*. National Water Well Association, Dublin, Ohio.
- Stow, S. H., and C. S. Haase. 1986. Subsurface disposal of liquid low-level radioactive wastes at Oak Ridge, Tennessee. *Ground Water Monit. Rev.* 6(3):49-52.
- Stow, S. H., C. S. Haase, and H. Weeren. 1985. Waste disposal by hydrofracture and application of the technology to the management of hazardous wastes. *International Conference on New Frontiers for Hazardous Waste Management*. EPA/600/9-85/025. U.S. Environmental Protection Agency, Washington, D.C.
- Suter, G. W., II. 1985. Application of environmental risk analysis to engineered organisms. pp. 211-219. IN H. D. Halverson, D. Pramer, and M. Rogul (eds.), *Engineered Organisms in the Environment*. American Society for Microbiology, Washington, D.C.
- Suter, G. W., II. 1985. QSAR in Environmental Toxicology (book review). *Environ. Int.* 10:475-476.
- Suter, G. W., II, L. W. Barnthouse, J. E. Breck, R. H. Gardner, and R. V. O'Neill. 1985. Extrapolating from the laboratory to the field: How uncertain are you? *Aquatic Toxicology and Hazard Assessment, Proc., 7th Symposium*. ASTM Special Tech. Publ 854:400-413. American Society for Testing and Materials, Philadelphia.
- Suter, G. W., II, L. W. Barnthouse, S. R. Kraemer, M. E. Grismer, D. W. Durnford, D. E. McWorter, F. R. O'Donnell, C. F. Baes III, and A. E. Rosen. 1986. Environmental risk analysis for oil from shale. ORNL/TM-9808.

- Suter, G. W., II, L. W. Barnthouse, and R. V. O'Neill. 1986. Treatment of risk in environmental impact assessment. pp. 107-133. IN C. T. Miller, P. R. Kleindorfer, and R. E. Munn (eds.), Conceptual Trends and Implications for Risk Research, Report of the Task Force Meeting on Risk and Policy Analysis Under Conditions of Uncertainty. International Institute for Applied Systems Analysis, Laxenburg, Austria.
- Suter, G. W., II, and A. E. Rosen. Comparative toxicology of marine fishes and crustaceans. National Oceanic and Atmospheric Administration report. NOAA, Rockville, Maryland (in press).
- Taylor, G. E., Jr., and C. A. Gunderson. 1986. The response of foliar gas exchange to exogenously applied ethylene. *Plant Physiol.* 82:163-170.
- Taylor, G. E., Jr., and R. J. Norby. 1985. The significance of elevated levels of ozone on natural ecosystems of North America. pp. 152-175. IN S. D. Lee (ed.), International Specialty Conference on Evaluation of the Scientific Basis for Ozone/Oxidant Standard. Air Pollution Control Association, Pittsburgh.
- Taylor, G. E., Jr., R. J. Norby, S. B. McLaughlin, A. H. Johnson, and R. S. Turner. 1986. Carbon dioxide assimilation and growth of red spruce (*Picea rubens* Sarg.) seedlings in response to ozone, precipitation chemistry, and soil type. *Oecologia* 70:163-171.
- Taylor, G. E., Jr., D. T. Tingey, and C. A. Gunderson. 1986. Photosynthesis, carbon allocation, and growth of sulfur dioxide ecotypes of *Geranium carolinianum*. *Oecologia* 68:350-357.
- Tolbert, V. R., A. M. Goldsmith, and J. J. Beauchamp. 1985. Comparison of growth responses of creek chubs from an undisturbed and a surface-mining disturbed stream. pp. 24-38. IN L. B. Starnes (ed.), Fish and Wildlife Relationships to Mining. Special Publication of the Water Quality Section, American Fisheries Society, Washington, D.C.
- Trabalka, J. R. (ed.). 1985. Atmospheric Carbon Dioxide and the Global Carbon Cycle. DOE/ER-0239. U.S. Government Printing Office, Washington, D.C.
- Trabalka, J. R., and D. E. Reichle (eds.). 1986. The Changing Carbon Cycle: A Global Analysis. Springer-Verlag, New York.
- Trabalka, J. R., J. Edmonds, R. H. Gardner, J. Reilly, and D. E. Reichle. 1986. Atmospheric carbon dioxide projections with globally averaged models. pp. 544-569. IN Proc., 6th Life Sciences Symposium, The Changing Carbon Cycle: A Global Analysis. Springer-Verlag, New York.
- Turner, R. R., M. A. Bogle, M. A. Kane, T. M. Mercier. 1986. Characterization of Y-12 Plant coal ash discharge to McCoy Branch. Y-12 Report Y/TS-177.
- Turner, R. R., M. A. Bogle, B. L. Kimmel, D. M. Soballe. 1986. Nature of pH variations at Rogers Quarry. Y-12 Report Y/TS-179.
- Turner, R. R., and K. F. Steele. Cadmium and manganese sorption by soil macropore coatings and fillings. *Soil Sci.* (in press).

- Turner, R. S., D. W. Johnson, J. W. Elwood, W. Van Winkle, R. B. Clapp, M. L. Jones, D. R. Marmorek, K. W. Thornton, S. A. Gherini, J. L. Schnoor, K. N. Eshleman, G. R. Holdren, Jr., P. W. Shaffer, J. O. Reuss, R. B. Cook, and M. R. Church. Factors affecting the long-term response of surface waters to acidic deposition: State of the science. ORNL/M-152 (in press).
- Turner, R. S., D. W. Johnson, J. W. Elwood, W. Van Winkle, R. B. Clapp, and J. O. Reuss. 1986. Factors affecting response of surface waters to acidic deposition. ORNL/TM-9787.
- Turner, R. S., R. J. Luxmoore, and K. W. Watson. 1985. Controls on hydrologic transport of trace elements in contrasting watersheds. p. 40. IN Proc., International Union of Forest Research Organisations Symposium on Water and Nutrient Movement in Forest Soils: Spatial and Temporal Variation. U.S. Forest Service, Durham, New Hampshire.
- Turner, R. S., R. J. Olson, and C. C. Brandt. 1986. Areas having soil characteristics that may indicate sensitivity to acidic deposition under alternative forest damage hypotheses. ORNL/TM-9917.
- Tyndall, R. L., J. A. Solomon, S. W. Christensen, and C. B. Fliermans. 1985. Legionnaires' disease bacteria in power plant cooling systems: Downtime report. Electric Power Research Institute, Palo Alto, California.
- Urban, D., R. V. O'Neill, and H. H. Shugart. Landscape ecology. BioScience (in press).
- Van Hook, R. I. Introduction. Chapter 1. IN D. W. Johnson and R. I. Van Hook (eds.), Analysis of Forested Watershed Processes. Springer-Verlag, New York (in press).
- Van Hook, R. I. Implications of Walker Branch watershed research. Chapter 10. IN D. W. Johnson and R. I. Van Hook (eds.), Analysis of Forested Watershed Processes. Springer-Verlag, New York (in press).
- Von Damm, K. L. 1986. Submarine hot spring chemistry (abstract). EOS 67:391.
- Von Damm, K. L. Experimental determination of quartz solubility in seawater under seafloor hydrothermal conditions. IN Proc., American Geophysical Union Fall Meeting, San Francisco, 1986 (in press).
- Von Damm, K. L., and J. L. Bischoff. Chemistry of hydrothermal solutions from the southern Juan de Fuca Ridge. J. Geophys. Res. (submitted).
- Voorhees, L. D., R. M. Cushman, M. A. Faulkner, and B. M. Horwedel. 1986. Data base management for the Remedial Action Program at Oak Ridge National Laboratory. ORNL/TM-9997.
- Walton, B. T. 1986. Risky business. Environ. Toxicol. Chem. 4:719-720.
- Walton, B. T. 1986. President's Message. SETAC NEWS, Vol. 6, No. 1.
- Walton, B. T. 1986. Message from SETAC's President. SETAC NEWS, Vol. 6, No. 2.
- Walton, B. T. 1986. Message from SETAC's President. SETAC NEWS, Vol. 6, No. 3.
- Walton, B. T. (Series coeditor with C. H. Ward). 1986. Environmental Hazard Assessment of Effluents by H. L. Bergman, R. A. Kimerle, and A. W. Maki. Pergamon Press, Oxford.

- Walton, B. T., and N. T. Edwards. 1986. Accumulation of organic waste constituents in terrestrial biota. pp. 73-86. IN R. C. Loehr (ed.), Land Treatment: A Hazardous Waste Management Alternative. University of Austin Press, Austin, Texas.
- Walton, B. T., J. S. Edwards, E. G. O'Neill, and S. -W. Che. 1986. Postembryonic development of teratogen-induced supernumary eyes in *Acheta domesticus* (L.) (Orthoptera:Gryllidae). Int. J. Insect Morphol. Embryol. 15:65-72.
- Winner, W. E., T. B. Leininger, and S. B. McLaughlin. 1986. Forest response to air-borne chemicals. pp. 22-44. IN Atmospheric Deposition and Forest Productivity, Proc., Fourth Annual Technical Conference. Society of American Foresters, Raleigh, North Carolina.
- Wright, L. L., and J. S. Mattice. 1985. Emergence patterns of *Hexagenia bilineata*: Integration of laboratory and field data. Freshwater Invertebr. Biol. 4:109-124.
- Wright, L. L., R. D. Perlack, P. A. Layton, C. R. Wensel, J. L. Trimble, and J. W. Ranney. 1985. Short Rotation Woody Crops Program quarterly progress report for the period June 1 to August 31, 1985. ORNL/TM-9832.
- Yeh, G. T. 1986. A subregional block-iteration finite element model of aquifer contaminant transport. EOS Trans. Am. Geophys. Union 66:905.
- Yeh, G. T. 1986. An orthogonal-upstream finite element approach to modeling aquifer contaminant transport. Water Resour. Res. 22(6):952-964.
- Yeh, G. T., K. V. Wong, P. M. Craig, and E. C. Davis. 1986. Development and applications of two finite element groundwater flow and contaminant transport models: FEWA and FEMA. pp. 775-785. IN Proc., 7th Annual Participants' Information Meeting, DOE Low-Level Waste Management Program, Las Vegas.

Presentations

Adams, S. M.

"Use of biological indicators for detecting sublethal acidification stress in fish populations: Advantages and limitations," 2nd Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985.

"Predator-prey relationships and food-web dynamics in reservoirs," invited seminar, University of Missouri, Columbia, November 1985.

Adams, S. M., and C. A. Burtis

"Biochemical and physiological responses of rainbow trout to varying durations of acidification stress," 115th Annual Meeting of the American Fisheries Society, Sun Valley, Idaho, September 1985.

Adams, S. M., and D. L. DeAngelis

"Indirect effects of early bass-shad interactions on prey availability and predator population structure," 116th Annual Meeting of the American Fisheries Society, Providence, Rhode Island, September 1986.

Auerbach, S. I.

"Comparative forest ecosystem behavior of three long-lived radionuclides," Seminar on the Cycling of Long-Lived Radionuclides in the Biosphere: Observations and Models, Madrid, Spain, September 1986.

Barnthouse, L. W.

"Incorporating relative toxicity estimation into site ranking assessments: Prioritization techniques and ranking methods," meeting, East Tennessee Chapter of the Society for Risk Analysis, Oak Ridge, Tennessee, July 1986.

Barnthouse, L. W., G. W. Suter II, and A. E. Rosen

"Extrapolating fish population responses from toxicity test data," annual meeting, Ecological Society of America, Syracuse, New York, August 1986.

Blasing, T. J.

"Tree-ring analysis of past environments," Botany 6320 class, University of Tennessee, Knoxville, October 1985.

"Dendroclimatology: The tree-ring circus comes to town," class lecture, Geology Department, University of Tennessee, Knoxville, February 1986.

Blaylock, B. G.

"Analysis of Chernobyl data," Commission of the European Communities Contractors' Meeting on the Environmental Transfer of Radionuclides; Implications of Chernobyl on Terrestrial and Aquatic Environments, Brussels, Belgium, June 1986.

Blaylock, B. G., F. O. Hoffman, and M. L. Frank

"Tritium in aquatic systems," Commission of the European Communities Workshop on Environmental and Human Risks of Tritium, Karlsruhe, West Germany, February 1986.

"Validation of technetium concentration factors for freshwater fish and invertebrates," Commission of the European Communities/Department of Energy Workshop on Research Status and Needs, Behavior of Technetium in Terrestrial and Aquatic Environments, Seattle, Washington, May 1986.

Bogle, M. A.

"Continuous, remote monitoring of stage and pH of low-order streams in the GSMNP," annual review meeting, Aluminum in Streams Study (ALSS), Electric Power Research Institute, Washington, D.C., April 1986.

Bondietti, E. A., and C. Papastefanou

"Aerodynamic size associations of natural radioactivity with atmospheric aerosols," annual meeting, American Chemical Society, New York, April 1986; and 2nd International Aerosol Conference, Berlin, September 1986.

Breck, J. E.

"Demonstrating PHALCA: A microcomputer model for estimating the survival of brook trout early life stages exposed to different combinations of pH, aluminum, and calcium," poster session, 116th Annual Meeting of the American Fisheries Society, Providence, Rhode Island, September 1986.

Breck, J. E., J. J. Beauchamp, and C. G. Ingersoll

"PHALCA: A microcomputer model for estimating the survival of brook trout early life stages in different combinations of pH, aluminum, and calcium," 116th Annual Meeting of the American Fisheries Society, Providence, Rhode Island, September 1986.

Breck, J. E., D. L. DeAngelis, and W. Van Winkle

"Simulating fish exposure to toxicants in a heterogeneous body of water," 1986 Summer Computer Simulation Conference, Reno, Nevada, July 1986.

Breck, J. E., and C. G. Ingersoll

"Modeling the mortality of early life stages of brook trout in response to fluctuating levels of pH, calcium, and aluminum," 6th Annual Meeting of the Society of Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985.

Cada, G. F.

"Cumulative effects of hydropower development" and "Turbine mortality studies," U.S. Environmental Protection Agency Small Hydropower Workshop, Chicago, October 1985.

Cada, G. F., J. M. Loar, and D. K. Cox

"Feeding preferences of rainbow and brown trout in southern Appalachian softwater streams," poster session, annual meeting, Ecological Society of America, Syracuse, New York, August 1986.

Christensen, S. W., J. E. Breck, and W. Van Winkle

"A framework for linking laboratory exposure studies to fish occurrence in the field," Workshop on Predicting Responses of Fish Populations to Acidification, Oak Ridge, Tennessee, May 1986.

Cook, R. B.

"Aluminum speciation and solubility in Walker Camp Prong," annual review, Ecological Effects of Acidification on Low-Order Woodland Streams Study, Electric Power Research Institute, Washington, D.C., April 1986.

Coutant, C. C.

"Striped bass, temperature, and dissolved oxygen: Problems for Cherokee Reservoir," invited seminar, East Tennessee State University, Johnson City, October 1985.

"Site-specific pollution regulation: A 'zero-base' perspective," invited talk, U.S.-Canada 12th Annual Aquatic Toxicity Workshop, Thunder Bay, Ontario, November 1985.

"Poor reproductive success of striped bass due to summer habitat limitations?" annual meeting, Tennessee Chapter of the American Fisheries Society, Henry Horton State Park, Tennessee, February 1986.

"CO₂ buildup global impact: A state-of-the-art report," Research Committee meeting, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 1986.

"Striped bass, temperature, and dissolved oxygen: Hypotheses of environmental degradation applied to Chesapeake Bay," invited seminar, U.S. Environmental Protection Agency Chesapeake Bay Program, May 1986; and invited talk, Gordon Research Conference on Estuarine Processes, Plymouth, New Hampshire, June 1986.

"Water quality and temperature effects on habitat suitability for striped bass in Chesapeake Bay," invited seminar, U.S. Environmental Protection Agency, Office of Marine and Estuarine Protection, Washington, D.C., June 1986.

"Atmospheric CO₂ and global climate change," 1986 Summer Seminar Series, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 1986.

Cushman, J. H.

"The U.S. Department of Energy's Herbaceous Energy Crops Program: An overview after one year," Sixth Annual Solar, Biomass, and Wind Energy Workshop, Atlanta, February 1986.

"U.S. Department of Energy Herbaceous Energy Crops Program," Technical Advisory Committee meeting, Great Lakes Regional Biomass Program, St. Paul, Minnesota, June 1986.

"Herbaceous Energy Crops Program progress report," annual management review, U.S. Department of Energy, Biofuels and Municipal Waste Technology Division, Washington, D.C., July 1986.

"Herbaceous Energy Crops Program: Recent developments and new initiatives," annual subcontractors' review, Herbaceous Energy Crops Program, Richmond, Virginia, August 1986.

Cushman, R. M., M. P. Farrell, and F. A. Koomanoff

"Climate predictions and regional resource analysis," Symposium on CO₂ and Climatic Change (joint meeting of the European Geophysical Society and European Seismological Commission), Kiel, Federal Republic of Germany, August 1986.

Cutshall, N. H.

"Cosmogenic ⁷Be as a tracer for short-term estuarine processes," International Laboratory of Marine Radioactivity, Monaco, November 1985.

"Shallow land burial: The flip-side of ocean dumping for disposal of low-level radioactive wastes," Ocean Disposal Symposium, Asilomar, California, April 1986.

Dale, V. H.

"Testing growth-decline hypotheses using a model of forest development," Tennessee Valley Authority 2nd Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985.

Dale, V. H., R. H. Gardner, and J. Pastor

"The use of an individual-based tree model to assess growth decline," Department of Forestry, University of Tennessee, Knoxville, February 1986.

Dale, V. H., R. H. Gardner, J. J. Pastor, Y. Jager, A. Rosen, and J. Horwedel

"Using a community dynamics model for studies of air pollution effects," Workshop, National Precipitation Assessment Program, Charlottesville, Virginia, November 1985.

Dale, V. H., R. H. Gardner, and P. S. White

"Understanding landscape pattern in the Great Smoky Mountains: Interaction of scale-dependent ecosystem processes," poster session, annual meeting, Ecological Society of America, Syracuse, New York, August 1986.

Dale, V., R. Gardner, P. White, and M. Huston

"Space, time, disturbance: Problems and perspectives in the Smoky Mountains," Symposium on the Role of Landscape Heterogeneity in the Spread of Disturbance, University of Georgia, Athens, January 1986.

DeAngelis, D. L.

"Modeling size distribution effects on early bass-shad interactions," Southeastern Mathematical Ecology Conference, Raleigh, North Carolina, March 1986.

"Modeling the development of size distributions in animals and plants," Institute of Ecosystem Studies, The New York Botanical Garden, Millbrook, New York, May 1986.

"Individual-based models of animal and plant populations," 4th International Congress of Ecology, Syracuse, New York, August 1986.

DeAngelis, D. L., J. A. Kitchell, and W. M. Post

"Long-term coevolution between marine snails and bivalve prey?" Dartmouth University, Hanover, New Hampshire, February 1986.

DeAngelis, D. L., and W. M. Post

"Positive feedback and ecosystem organization," 4th International Congress of Ecology, Syracuse, New York, August 1986.

Edwards, N. T.

"Assimilation and metabolism of polycyclic aromatic hydrocarbons by vegetation: An approach to this controversial issue and suggestions for future research," 10th Anniversary International Symposium on Polynuclear Aromatic Hydrocarbons (PAHs), Battelle Columbus Laboratory, Columbus, Ohio, October 1985.

Elwood, J. W., C. T. Driscoll, R. R. Turner, P. J. Mulholland, C. L. Schofield, M. A. Bogle, and D. M. Genung

"The chemistry of acidic woodland streams in the Great Smoky Mountains, Tennessee, and the Adirondack Mountains, New York," Muskoka Conference '85, International Symposium on Acidic Precipitation, Muskoka, Ontario, Canada, September 1985.

"Acid-base chemistry of streams in the GSMNP," annual review, Aluminum in Streams Study (ALSS) Project, Electric Power Research Institute, Washington, D.C., April 1986.

Emanuel, W. R.

"Increasing atmospheric CO₂ and the global carbon cycle," Science Teachers Research Involvement for Vital Education Program (STRIVE), University of Tennessee and Oak Ridge Associated Universities, June 1986.

"Discussion of theory of spatially distributed systems and advanced computer systems: Array and parallel computation in landscape dynamics," workshop organized by Colorado State University, Pingree Park, September 1986.

Gardner, R. H., V. H. Dale, and P. S. White

"Determinants of landscape pattern in a heterogeneous environment," 12th Annual Scientific Research Meeting, Great Smoky Mountains National Park, Gatlinburg, Tennessee, May 1986.

Gardner, R. H., D. L. DeAngelis, V. H. Dale, J. W. Webb, and C. Eager

"Projecting vegetation dynamics following insect disturbance on a heterogeneous landscape," Symposium on the Role of Landscape Heterogeneity in the Spread of Disturbance, University of Georgia, Athens, January 1986; and Ecological Society of America/4th International Congress of Ecology, Syracuse, New York, August 1986.

Garten, C. T., Jr., and R. Lomax

"Technetium cycling in maple trees: Characterization of changes in chemical form," Conference on Behavior of Technetium in Terrestrial and Aquatic Environs, Battelle Seattle Research Center, Seattle, Washington, May 1986.

Garten, C. T., Jr., C. S. Tucker, and B. T. Walton

"Environmental fate of technetium-99 in a deciduous woodland," 6th Annual Meeting of the Society of Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985.

Haase, C. S.

"Petrology and diagenesis of the Pumpkin Valley Shale," ORAU Traveling Lecture Program, University of Alabama, Tuscaloosa, and Mississippi State University, Starkville, March 1986.

Hoffman, F. O.

"Radioecology in terrestrial and aquatic systems," Workshop on the Behavior of Radionuclides in Biological Systems, Baden, Switzerland, October 1985.

"The technical objectives of BIOMOVs," "A description of the three test scenarios for comparing model predictions of radionuclide accumulation in food chains," and "Phase A: Model validation—How to proceed with testing model predictions with data sets," First BIOMOVs Workshop, Baden, Switzerland, October 1985.

"Methods for evaluating the reliability of the predictions of environmental assessment models," International Atomic Energy Agency Technical Advisory Meeting, Vienna, Austria, November 1985.

"Preliminary information on the Chernobyl accident," Oak Ridge National Laboratory, Oak Ridge, Tennessee, May 1986.

"Radioecological aspects of the Chernobyl accident," Oak Ridge National Laboratory, Oak Ridge, Tennessee, June 1986.

"Strategies for evaluating environmental transfer factors," International Atomic Energy Agency Consultants Meeting on Environmental Transfer Factors, Carmel, California, June 1986.

"The extent of Chernobyl contamination in western Europe and the USA," Electric Power Research Institute, Palo Alto, California, June 1986.

"Environmental aspects of the Chernobyl accident," Oak Ridge Associated Universities, Oak Ridge, Tennessee, July 1986.

"Contamination of the environment by the Chernobyl accident," West Knoxville Rotary Club, Knoxville, Tennessee, August 1986.

Huston, M. A.

"Community and ecosystem patterns in a dynamic landscape," invited seminar, Ecological Society of America Symposium on Ecosystem and Community Implications of Population Processes, Syracuse, New York, August 1986.

Jacobs, G. K.

"The isolation of high-level nuclear waste: A geochemist's perspective," joint meeting, South-plains, Panhandle Plains, and Permian Basin sections, American Chemical Society, Lubbock, Texas, September 1986.

Jimenez, B. D., G. H. Ezell, Z. B. Egan, N. E. Lee, J. J. Beauchamp, and J. F. McCarthy

"Effects of feeding and temperature on the mixed function oxidase (MFO) system in bluegill sunfish, *Lepomis macrochirus*," annual meeting, Society of Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985.

Jimenez, B. D., S. D. Meads, and S. M. Adams

"The use of liver enzymes and liver conditions as sublethal indicators of contaminant stress in the redbreast sunfish, *Lepomis auritus*," Toxic Chemical and Aquatic Life: Research and Management Symposium, Seattle, Washington, September 1986.

Johnson, D. W.

"Effects of acid deposition on forest soils," International Union of Forest Research Organisations World Congress, Ljubljana, Yugoslavia, September 1986.

"Soil leaching in northern forest ecosystems," Symposium on Productivity of Northern Forests Following Biomass Harvesting, Burlington, New Hampshire, May 1986.

Johnson, D. W., and D. E. Todd

"Nitrogen availability and conservation in young yellow-poplar and loblolly pine plantations fertilized with urea," annual meeting, Soil Science Society of America, Chicago, December 1985.

Johnson, D. W., S. E. Lindberg, E. A. Bondietti, and R. B. Harrison

"Integrated forest studies of acid deposition," 2nd Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985.

Johnson, D. W., S. E. Lindberg, E. A. Bondietti, and L. F. Pitelka

"The integrated forest study on effects of atmospheric deposition," 1986 Annual Meeting, Technical Association of the Paper and Pulp Industry, Atlanta, Georgia, March 1986.

Kanciruk, P., L. Hook, and R. McCord

"Research data management for a large environmental survey," poster session, 10th International CODATA Conference, Ottawa, Canada, July 1986.

Kimmel, B. L., D. M. Soballe, and S. M. Adams

"The contribution of phytoplankton production to the organic carbon budget and food web dynamics of Normandy Reservoir," annual meeting, American Society of Limnology and Oceanography, University of Rhode Island, Narragansett, June 1986.

Layton, P. A., and L. L. Wright

"The role of genetic improvement in developing short-rotation woody crops," Institute of Gas Technology 10th Annual Meeting on Energy from Biomass and Wastes, Washington, D.C., April 1986.

Lee, S. Y.

"Progress report for soil mineralogy research activity at ORNL," Southern Regional Clay Mineralogy Work Group, Technical Committee S-152, U.S. Department of Agriculture, May 1986.

"Soils at Oak Ridge Reservation, Oak Ridge, Tennessee," annual report meeting, S-152 Committee, Southern Regional Soil Mineralogy Group, U.S. Department of Agriculture, University of North Carolina, Raleigh, May 1986.

"Role of earth science in the disposal of nuclear wastes," Department of Soil and Plant Sciences, University of Tennessee, Knoxville, June 1986; also, Soil Science Society of Korea, Korea Advanced Energy Research Institute and Korea Institute of Energy Resources, Seoul, Korea, June-July 1986.

"Radionuclide contamination characteristics of nuclear site soils in the Nevada Test Site (NTS)," Workshop for NTS contractors, Las Vegas, Nevada, September 1986.

"Summary report of Nuclear Site Soil Characterization Project," Nevada Applied Ecology Group, Las Vegas, Nevada, September 1986.

Loar, J. M., J. M. Giddings, S. M. Adams, J. F. McCarthy, and G. R. Southworth

"A biological monitoring plan for East Fork Poplar Creek," Oak Ridge Task Force Workshop, Chattanooga, Tennessee, October 1985.

"Case study: A biological monitoring plan for a Department of Energy facility," Pre-Conference Workshop on Biomonitoring: Testing and Compliance Procedures for NPDES Permits, Water Pollution Control Federation Annual Conference, Kansas City, Missouri, October 1985.

Loar, J. M., M. J. Sale, and G. F. Cada

"Instream flow needs for protection of fishery resources," Water Forum '86, American Society of Civil Engineers, Long Beach, California, August 1986.

Luxmoore, R. J., R. J. Norby, and E. G. O'Neill

"Seedling tree responses to nutrient stress under atmospheric CO₂ enrichment," 18th International Union of Forest Research Organisations World Congress, Ljubljana, Yugoslavia, September 1986.

Luxmoore, R. J., K. W. Watson, G. R. Southworth, R. R. Turner, and R. C. Ward

"Macropore and soil variability effects on hydrologic transport processes," 13th Congress of the International Society of Soil Science, Hamburg, Federal Republic of Germany, August 1986.

Mann, L. K.

"Nutrient allocation in forests and implication for whole-tree harvesting," poster session, annual meeting, Ecological Society of America, Syracuse, New York, August 1986.

McBrayer, J. F.

"Institutional and technical issues in the management of low-level mixed wastes," 3rd Annual Midwest Workshop and Technology Fair on Low-Level Radioactive Waste Management Post '86: Expectations and Looming Decisions, Columbus, Ohio, October 1985.

"Strategic National Alternatives Study (SNAS)," Waste Incineration Workshop, U.S. Department of Energy, Oak Ridge, Tennessee; and Technical Review Group Meeting, U.S. Department of Energy Hazardous Waste Remedial Actions Program, Augusta, Georgia, January 1986.

"Hazardous waste: How we got here, where we're going," Deep South Regional Meeting, National Federation of Garden Clubs, Chattanooga, Tennessee, March 1986.

"Managing mixed wastes: Technical issues," Waste Management '86, Tucson, Arizona, March 1986.

"DOE role in the Air Force IRP process," Air Force Systems Command Environmental Coordinators' Installation Restoration Program Workshop, Cocoa Beach, Florida, September 1986.

McCarthy, J. F.

"Effects of dissolved humic material on the transport, fate, and bioavailability of organic contaminants in aquatic systems," Oak Ridge Associated Universities Traveling Lecture Program, University of North Carolina, Wilmington; Virginia Polytechnic Institute and State University, Blacksburg; and Gannon University, Erie, Pennsylvania.

"Effect of dissolved macromolecules on the exposure of aquatic organisms to organic contaminants," Tenth Symposium on Aquatic Toxicology and Hazard Assessment, American Society for Testing and Materials, New Orleans, May 1986.

"Binding of organic contaminants to chromatographic fractions of dissolved humic material," Third International Meeting of the International Humic Substances Society, Oslo, Norway, August 1986.

McLaughlin, S. B.

"Estimating changes in forest growth as a function of air pollution," Kentucky/Tennessee Society of American Foresters, Bowling Green, Kentucky, January 1986.

"Some perspectives on methods for detecting and evaluating forest responses to air pollution," Eastern Hardwoods Research Cooperative meeting, Philadelphia, Pennsylvania, January 1986.

"Measuring and evaluating forest growth patterns in relation to air pollution," and "Measuring effects of ozone on plant systems," University of Uppsala, Sweden, and University of Omea, Sweden, April 1986.

"Sulfur and nitrogen oxide effects on forest systems: Evaluation of potential for effects and research needs," testimony before House Agriculture Subcommittee on Forest, Family, Farms, and Energy, Washington, D.C., May 1986.

"Detecting and evaluating effects of atmospheric pollutants on U.S. forests," United States-German Scientific Exchange, Knoxville, Tennessee, May 1986.

"Sulfur and nitrogen dioxide effects on forest systems: Evaluation of potential for effects and research needs," testimony before House Agricultural Subcommittee on Forest, Family Farms, and Energy, Washington, D.C., May 1986.

"Dendroecology as a research tool for evaluating forest responses to atmospheric pollution," Nature Conservancy Board of Directors, Washington, D.C., June 1986.

"Dendroecology as a research tool for evaluating environmental stress," INTECOL Symposium on Ecological Evidence to Assess Acid Deposition, Syracuse, New York, August 1986.

Mulholland, P. J., A. V. Palumbo, J. W. Elwood, and L. A. Ferren

"Effects of acidification on stream periphyton," 2nd Annual Tennessee Valley Authority Conference on Effects of Acid Precipitation in the Southeast, Gatlinburg, Tennessee, October 1985.

"Nutrient spiralling: A concept of nutrient cycling in ecosystems with strong advective transport," invited seminar, Biological Sciences Seminar Series, University of Mississippi, Oxford, February 1986.

"Effect of acidification on leaf decomposition in streams," annual meeting, Ecological Society of America, Syracuse, New York, August 1986.

Norby, R. J.

"Symbiotic nitrogen fixation in CO₂-enriched woody plants," International Union of Forest Research Organisations Conference on Roots in Forest Soils: Biology and Symbioses, Victoria, British Columbia, August 1986.

Norby, R. J., S. B. McLaughlin, and G. E. Taylor, Jr.

"Physiological indicators of acidic deposition stress in forest trees," 6th Annual Meeting of the Society on Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985.

Norby, R. J., and J. Pastor

"Carbon-nutrient interactions in response to CO₂ enrichment: Physiological and long-term perspectives," International Union of Forest Research Organisations Symposium on Coupling of Carbon, Water, and Nutrient Interactions in Woody Plant Soil Systems, Knoxville, Tennessee, October 1985.

Norby, R. J., G. E. Taylor, Jr., S. B. McLaughlin, and C. A. Gunderson

"Drought sensitivity of red spruce seedlings affected by precipitation chemistry," 9th North American Forest Biology Workshop, Stillwater, Oklahoma, June 1986.

Olson, R. J.

"Regional assessment of the effects of acidic deposition on aquatic resources," Environmental Studies/HRI Seminar Series, Butler University, Indianapolis, Indiana, September 1986.

Olson, R. J., D. L. Durfee, and D. L. Wilson

"Application of a geographic information system in the study of acidic deposition," Geographic Information Systems for Environmental Protection, University of Nevada, Las Vegas, January 1986.

"A geographic information system used to study acidic disposition," poster session, 10th International CODATA Conference, Ottawa, Canada, July 1986.

Olson, R. J., A. E. Rosen, C. T. Hunsaker, R. S. Turner, C. C. Brandt, R. C. Durfee, P. R. Coleman, D. L. Wilson, and F. E. Latham.

"The Adirondack Watershed data base: A resource for regional studies," Workshop on Regionalization of Aquatic Impacts Using the Adirondack Region as a Case Study, Paul Smith College, Paul Smith, New York, August 1986.

O'Neill, E. G., R. J. Luxmoore, and R. J. Norby

"Increases in mycorrhizal infection and seedling growth in two forest species grown in an enriched CO₂ atmosphere," International Union of Forest Research Organisations Symposium on Roots in Forest Soils: Biology and Symbioses, Victoria, British Columbia, Canada, August 1986.

O'Neill, E. G., R. J. Luxmoore, and R. J. Norby

"Growth and mycorrhizal colonization of white oak (*Quercus alba* L.) seedlings grown in unfertilized forest soil in an enriched CO₂ atmosphere," annual meeting, Ecological Society of America, Syracuse, New York, August 1986.

O'Neill, R. V.

"Hierarchy theory and global change," SCOPE Workshop, October 1985.

"Hierarchy and large scales," Colorado State University, December 1985.

"Landscape ecology," Department of Energy seminar, Washington, D.C., February 1986.

"Hierarchy theory and complex ecosystems," Ecological Society of America Symposium on Modeling Complex Ecosystems, Syracuse, New York, August 1986.

Palumbo, A. V.

"Microbial growth, respiration, and biomass on leaf material in acidified and non-acidified streams," 86th Annual Meeting, American Society for Microbiology, Washington, D.C., March 1986.

"Direct and indirect effects of acidification on bacterial production in streams," Joint American Society for Microbiology—Canada Society of Microbiology Symposium on Environmental Insult and Recovery of Stressed Systems, Toronto, Canada, June 1986.

"Effects of acidification on microbial communities in streams," annual review of Aluminum in Streams Study (ALSS) Project at Electric Power Research Institute headquarters, Washington, D.C., April 1986.

Palumbo, A. V., P. J. Mulholland, J. W. Elwood, L. A. Ferren, and D. M. Genung.

"Effects of acidification on microbial communities and processes," 2nd Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985.

Parr, P. D.

"Rare plant research at the Oak Ridge National Environmental Research Park," annual meeting, Ecological Society of America, Syracuse, New York, August 1986.

Parr, P. D., and R. K. Jones

"Initiation of long-term research on a rare plant population on the Oak Ridge National Environmental Research Park," annual meeting, Association of Southeast Biologists, Columbia, South Carolina, April 1986.

Peng, T.-H.

"Changes in deep ventilation rate over the last 7000 years," spring meeting, American Geophysical Union, Baltimore, Maryland, May 1986.

Peng, T.-H., and W. S. Broecker

"Modeling the distribution of tritium in the ocean," Ocean Sciences meeting, New Orleans, Louisiana, January 1986.

Ranney, J. W.

"Short-rotation research in the United States and abroad," 23rd Annual Meeting, Poplar Council of the United States, Seattle, Washington, July 1986.

D. E. Reichle

"The ORNL Environmental Sciences Division—National roles and regional relationships," Roane-Anderson Economic Council, Oak Ridge, Tennessee, November 1986.

"Activities of the Public Affairs Committee of the Ecological Society of America," Board of Directors, American Society of Limnology and Oceanography, Inc., Kingston, Rhode Island, June 1986.

"The ecologists' role in public affairs and public policy," American Society of Limnology and Oceanography, Inc., Kingston, Rhode Island, June 1986.

Salk, M. S.

"The potential for growing terrestrial energy crops in the southwestern United States," Institute of Gas Technology 10th Annual Meeting on Energy from Biomass and Wastes, Washington, D.C., April 1986.

Sharples, F. E.

"Ecologists and 'genetic engineers': Partners or adversaries?" invited seminar, Graduate Program in Ecology, Rutgers University, New Brunswick, New Jersey, March 1986.

"An update on the Hazardous Waste Remedial Actions Program (HAZWRAP): Integrating waste management," HAZMAT '86, Fourth Annual Hazardous Materials Management Conference, Atlantic City, New Jersey, June 1986.

"A brief introduction to the United States Congress," Roane-Anderson Economic Council, Oak Ridge, Tennessee, June 1986.

Sharples, F. E., and L. D. Eyman

"Impacts of hazardous waste regulation on low-level waste management," Eighth Annual Department of Energy Low-Level Waste Management Forum, Denver, Colorado, September 1986.

Shugart, L. R.

"Quantitating exposure to benzo[a]pyrene," Bioassay Branch, Toxicology and Microbiology Division, 1986 Seminar Series, Environmental Protection Agency ORDA, Health Effects Research Laboratory, Cincinnati, Ohio, December 1985.

"Measurement of DNA adducts using HPLC (fluorescence detection)," Department of Energy Workshop on the Measurement and Characterization of DNA Adducts, U.S. Department of Energy Office of Health and Environmental Research, Physical and Technological Research Division, Rockville, Maryland, May 1986.

Shugart, L. R., J. McCarthy, and B. Jimenez

"Biological markers of environmental contaminants: Analysis of P₄₅₀ activities and adduct formation in aquatic and terrestrial species exposed to benzo[a]pyrene," 2nd Annual U.S. Department of Energy Contractors Meeting, Delvan, Wisconsin, June 1986.

"Analysis of adduct formation in the bluegill sunfish exposed to benzo[a]pyrene," poster session, Symposium on Toxic Chemicals and Aquatic Life: Research and Management, Seattle, Washington, September 1986.

Smith, E. D., L. W. Barnthouse, G. W. Suter II, J. E. Breck, T. D. Jones, and D. A. Sanders

"Improving the risk relevance of systems for assessing the relative hazard of contaminated sites," 3rd National Conference on Hazardous Wastes and Hazardous Materials, Atlanta, March 1986.

Smith, E. D., and D. C. Kocher

"Is the Analytic Hierarchy Process a good tool for setting priorities for high-level radioactive waste research?" meeting, Prioritization Techniques/Ranking Methods, East Tennessee Chapter, Society for Risk Analysis, Oak Ridge, Tennessee, July 1986.

Soballe, D. M., and B. L. Kimmel

"Effect of heterogeneities on the field estimation of phytoplankton biomass by in vivo chlorophyll fluorescence," joint annual meeting, American Society of Limnology and Oceanography and the Phycological Society of America, University of Rhode Island, Narragansett, June 1986.

Solomon, A. M.

"The CO₂ issue: Relevance of prehistoric forest histories," Ecology Seminar, University of Minnesota, Minneapolis, October 1985.

"Recent research on CO₂ and the global carbon cycle," Forest Ecology class, University of Minnesota, Minneapolis, October 1985.

"Linking GCM climate data with data from static dynamic vegetation models," Workshop on Climate and Vegetation Interactions, National Atmospheric and Space Administration, Goddard Space Flight Center, Green Belt, Maryland, January 1986.

"Models for analyzing ecosystem effects of elevated CO₂," U.S. Department of Energy Meeting on CO₂ Modeling, Raleigh, North Carolina, March 1986.

"Atmospheric carbon dioxide change: Agent of future forest growth or decline?" United Nations Environmental Programme/U.S. Environmental Protection Agency International Conference on Health and Environmental Effects of Ozone Modification and Climate Change, Arlington, Virginia, June 1986.

Solomon, J. A.

"Flagellar root systems indicate a euglenoid-kinetoplastid connection," seminar, Botany Department, University of Tennessee, Knoxville, June 1986.

"Flagellar root systems: Evidence for a euglenoid-kinetoplastid connection," annual meeting, Phycological Society of America, Kingston, Rhode Island, June 1986.

"Flow cytometry techniques for species improvement," subcontractors' annual review meeting, Aquatic Species Program, Solar Energy Research Institute, Golden, Colorado, September 1986.

Southworth, G. R., and K. W. Watson

"Comparison of models for describing the transport of retarded tracers in macroporous soils," 6th Annual Meeting of the Society of Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985.

Stow, S. H.

"The impact of recently enacted federal legislation on demand for geoscientists," Southeastern Section meeting, Geological Society of America, Memphis, Tennessee, April 1986.

Stow, S. H., and C. S. Haase.

"Subsurface disposal of liquid low-level radioactive wastes at Oak Ridge, Tennessee," 19th Congress of the International Association of Hydrogeologists, Karlovy Vary, Czechoslovakia, September 1986.

Suter, G. W., II

"Treatment of risk in environmental impact assessment," International Institute for Applied Systems Analysis Task Force Meeting on Risk and Policy Analysis Under Conditions of Uncertainty, Laxenburg, Austria, November 1985.

Suter, G. W., II, and A. E. Rosen

"Endpoints for chronic toxicity to fish," 6th Annual Meeting of the Society of Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985.

Taylor, G. E., Jr., and C. A. Gunderson

"Ethylene effects on photosynthesis in *Glycine max*: A nonstomatal site of action," annual meeting, American Society of Plant Physiologists, Louisiana State University, Baton Rouge, June 1986.

Taylor, G. E., Jr., R. J. Norby, and S. B. McLaughlin

"Methodologies for wet deposition research," International Workshop on Exposure Methods for Investigating Forest Effects of Air Pollution, Oregon State University/U.S. Environmental Protection Agency, Corvallis, January 1986.

"Deposition of trace gases to vegetation: Sites of regulation and relationship to plant response," General Motors Research Laboratories, Warren, Michigan, April 1986.

"The influence of ozone, precipitation chemistry, and soil type on red spruce (*Picea rubens*)," annual meeting, American Society of Plant Physiologists, Louisiana State University, Baton Rouge, June 1986.

"Population differentiation in response to sulphur dioxide: A case study in *Geranium carolinianum* L.," University of Lancaster, Lancaster, United Kingdom, September 1986.

Tripathi, V. S., and G. T. Yeh.

"HYDROGEOCHEM: A new model for transport of reactive multispecies contaminants," fall meeting, American Geophysical Union, San Francisco, California, December 1985.

Tripathi, V. S., and G. T. Yeh

"Transport and geochemical reaction modeling in brines," American Chemical Society Symposium on Origin and Evolution of Brines in the Subsurface, Anaheim, California, September 1986.

Tripathi, V. S., G. T. Yeh, G. K. Jacobs, A. D. Kelmers

"Performance assessment of high-level nuclear waste repositories: Can K_d 's represent geochemical reality?" American Chemical Society Symposium on Geochemical Aspects of Radioactive Waste Disposal, Anaheim, California, September 1986.

Von Damm, K. L.

"Experimental determination of quartz solubility in seawater under seafloor hydrothermal conditions," fall meeting, American Geophysical Union, San Francisco, December 1985.

"Submarine hot spring chemistry," spring meeting, American Geophysical Union, Baltimore, Maryland, May 1986.

Walton, B. T.

Incoming President's Message, annual meeting, Society of Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985.

"The role of Regional Chapters in the Society of Environmental Toxicology and Chemistry," annual meeting, Ozark Prairie Chapter of the Society of Environmental Toxicology and Chemistry, Columbia, Missouri, May 1986.

Watts, J. A.

"Demonstration of PC-based system for Southern Blue Ridge Province Soil Survey (Form 232)," Field Sampling Protocol Workshop, Environmental Protection Agency, University of Tennessee, Knoxville, March 1986.

Wright, L. L.

"SRWCP strategy for reducing biological risks in wood energy plantations," status briefing to J. Ferrell, Manager of DOE's Short Rotation Woody Crops Program, Department of Energy, Washington, D.C., April 1986.

"Some factors affecting stand level structure in SRIC plantations," "Structure" session, annual meeting, Short Rotation Woody Crops Program, Ames, Iowa, August 1986.

"Short rotation forestry," Northeast Regional Biomass Program Steering Committee, Portsmouth, New Hampshire, September 1986.

Wright, L. L., and J. W. Ranney

"Maximizing wood energy production in short-rotation plantations: Effect of initial spacing and rotation length," annual meeting, Poplar Council of the United States, Seattle, Washington, July 1986.

Theses

Groeger, A. W. 1986. Photosynthetic carbon metabolism in freshwater phytoplankton. Ph.D. dissertation. University of Oklahoma, Norman.

Solomon, J. A. 1986. Euglenoid flagellar root systems. Ultra structure and phylogenetic significance. Ph.D. dissertation. University of Tennessee, Knoxville.

Professional Activities

ADAMS, S. M.

Participant: Invited speaker, Annual Meeting of the American Fisheries Society, Sun Valley, Idaho, September 1986; invited panel member, Annual Meeting of the American Fisheries Society, September 1986; invited speaker, 2nd Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985; invited workshop participant, Environmental Concerns of the Chesapeake Bay, Annapolis, Maryland, June 1986.

Faculty: Adjunct faculty, University of Tennessee.

Advisor: Mark S. Bevelheimer, Ph.D. candidate, University of Tennessee; Ken L. Shepard, M.S. candidate, University of Tennessee; Denise Benson, M.S. candidate, University of Tennessee; Lisa S. Burtis, M.S. candidate, University of Tennessee; Gabriela Cacheiro, B.A. candidate, University of Tennessee.

Ad hoc reviewer: *Transactions of the American Fisheries Society, Canadian Journal of Fisheries and Aquatic Sciences, Fisheries; Proceedings, Annual Conference of Southern Fisheries and Wildlife Agencies.*

Other: Editorial board, Biological Communities of the Southeastern United States (aquatic volume); American Fisheries Society Distinguished Service Award Committee; Poster and Student Paper Awards Committee of the American Fisheries Society.

AUERBACH, S. I.

Chairman: Interdisciplinary Review Group, Tennessee-Tombigbee Waterway, Mobile, Alabama, 1986; General Assembly of the International Union of Radioecologists (President of Board of Council), Madrid, Spain, September 1986.

Member: Executive Committee, Science Advisory Board, U.S. Environmental Protection Agency, 1986–1988; Municipal Waste Combustion Subcommittee, Science Advisory Board, U.S. Environmental Protection Agency, 1986; Advisory Board, Department of Geological Sciences, University of Tennessee, 1986; Advisory Panel, Presidential Young Investigator Nominations, National Science Foundation, 1986; Editorial Board, *Environmental and Experimental Botany*; Editorial Board, *Environment International*; Steering Committee for the Scientific Committee on Problems of the Environment—International Association for Ecology—International Council of Scientific Unions (SCOPE—INTECOL—ICSU) Workshop on Spatial and Temporal Variability for Biospheric and Geospheric Processes, National Research Council, 1986.

Participant: Seminar on Cycling of Long-Lived Radionuclides, Madrid, Spain, September 1986.

BAES, C. F., III

Chairman: Experimental Design and Data Management Workshop for the Environmental Protection Agency Forest Response Program, Raleigh, North Carolina, March 1986.

Member: Integration/assessment team for the Environmental Protection Agency—U.S. Department of Agriculture/Forest Service Forest Response Program.

Participant: International Symposium on Whole Plant Physiology, Knoxville, Tennessee, October 1985; Exposure Systems Workshop for the Environmental Protection Agency Forest Response Program, Raleigh, North Carolina, March 1986; Laboratory Analytical Techniques Workshop for the Environmental Protection Agency Forest Response Program, Raleigh, North Carolina, March 1986; Site Classification and Field Measurements Workshop for the Environmental Protection Agency Forest Response Program, Raleigh, North Carolina, March 1986.

Ad hoc reviewer: *Canadian Journal of Forest Research*; proposals: NSF; Natural Environmental Research Council, United Kingdom; U.S. Department of Agriculture, Forest Service.

BARNTHOUSE, L. W.

Member: National Research Council Committee on Pyrethroids and Ecological Risk Assessment.

Participant: 1985 Washington Conference on Environmental and Health Risk Assessment, Alexandria, Virginia, October 1985; Workshop on Approaches to Ecological and Human Health Risk Analysis for Disposal of Contaminated Sediments and Human Consumption of Contaminated Seafood, Seattle, Washington, December 1986; East Tennessee Chapter, Society for Risk Analysis Workshop: Risk Analysis Methods Day, Knoxville, Tennessee, April 1986; East Tennessee Chapter, Society for Risk Analysis Workshop: Prioritization Techniques and Ranking Methods, Oak Ridge, Tennessee, July 1986; International Congress of Ecology, Syracuse, New York, August 1986.

Ad hoc reviewer: *Fisheries Research, Risk Analysis*; Electric Power Research Institute, Nebraska Public Power District, U.S. Army Corps of Engineers; proposals: U.S. Air Force.

BARTELL, S. M.

Member: Environmental Sciences Division Computer Advisory Committee.

Advisor: Alan Johnson, Ph.D. candidate, University of Tennessee.

Ad hoc reviewer: *Environmental Science and Technology, Aquatic Toxicology*; NSF proposals; review panel for Environmental Protection Agency Environmental Biology Competitive Grants Program.

BLASING, T. J.

Faculty: Adjunct Assistant Professor, Geography Department, University of Tennessee.

Ad hoc reviewer: *Journal of Climate and Applied Meteorology, Science, Tree-Ring Bulletin, Climatic Change, Monthly Weather Review, Journal of Environmental Quality*; proposals: NSF.

BLAYLOCK, B. G.

Member: National Council on Radiation Protection and Measurements, Committee 64, Task Group 2; Committee on Research on the Validation of Predictive Models Using Chernobyl Data; Oak Ridge Task Force, Task Group V, Environmental Health and Risk Analysis; Union of Radioecologists Working Group, Radioecology of Major Rivers.

Participant: Session Chairman, Commission of the European Communities/Department of Energy Cosponsored Symposium on the Behavior of Tc in Terrestrial and Aquatic Environs, Seattle, Washington, May 1986; Department of Energy/Office of Health and Environmental Research Workshop on the Validation and Testing of Mathematical Models with Real Data Sets, Washington, D.C., April 1986; BIOMOVs Workshop on International Biospheric Model Validation, Paris, France, February 1986.

Faculty: Adjunct Professor, University of Tennessee.

Advisor: James Fox, M.S. candidate, University of Tennessee; Linda Meyers, Ph.D. candidate, University of Tennessee.

Ad hoc reviewer: *Health Physics*; DOE proposal.

BODEN, T. A.

Participant: 10th International CODATA Conference, International Council of Scientific Unions, Ottawa, Canada, July 1986.

BOEGLY, W. J., Jr.

Member: Committee on Utilities (A1A03), Transportation Research Board, National Academy of Sciences/National Academy of Engineering; Dual Systems Committee, American Water Works Association; Working Commission W-62 (National Academy of Sciences/National Research Council) on Water Supply and Drainage in Buildings; Committee D-34 on Waste Disposal, Secretary, Subcommittee D-34.05 on Liner Systems, American Society for Testing and Materials; Research Committee, Water Pollution Control Federation.

Faculty: Part-time Associate Professor, University of Tennessee, Civil Engineering Department.

Ad hoc reviewer: EPRI and DOE proposals.

Other: Environmental Sciences Division Energy Conservation Coordinator.

BOGLE, M. A.

Participant: Second Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985; Annual Review, Electric Power Research Institute Stream Acidification Project, Washington, D.C., April 1986.

Ad hoc reviewer: Proceedings of the Biological Society of Washington.

BONDIETTI, E. A.

Participant: American Chemical Society Symposium on Radon, New York City, April 1986; 2nd International Aerosol Symposium, Berlin, September 1986.

Witness: House Committee on Agriculture: Presented testimony on industry funding of acid rain effects research, May 1986.

Ad hoc reviewer: *Journal of Environmental Radioactivity.*

Other: Associate editor, *Journal of Environmental Radioactivity.*

BOSTON, H. L.

Participant: Second Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985; Environmental assessment of aquatic impacts resulting from the operation of Agrifuel's fuel ethanol plant in the port of New Iberia, Louisiana.

Ad hoc reviewer: Proposal: NSF Ecology Section; *Aquatic Botany*; IES for Remedial Action Plan for Department of Energy's Weldon Spring site.

BRECK, J. E.

Participant: Second Annual Acid Rain Conference for the Southern Appalachians, Tennessee Valley Authority, Gatlinburg, Tennessee, October 1985; Sixth Annual Meeting, Society of Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985; Workshop on Predicting Responses of Fish Populations to Acidification, Oak Ridge, Tennessee, May 1986; 116th Annual Meeting, American Fisheries Society, Providence, Rhode Island, September 1986; preparation of Chemical Stockpile Disposal Program Draft Programmatic Environmental Impact Statement.

Ad hoc reviewer: *Canadian Journal of Fisheries and Aquatic Sciences, Environment International.*

Other: Division Coordinator for United Way.

CADA, G. F.

Participant: 71st Annual Meeting of the Ecological Society of America; preparation of Final Environmental Statement for the Owens River Basin Cluster Impact Assessment Procedure; Environmental Protection Agency Small Hydropower Workshop, Chicago, Illinois.

Consultant: U.S. Army Corps of Engineers, Mobile, Alabama.

Ad hoc reviewer: American Fisheries Society journals; DOE proposals.

CHRISTENSEN, S. W.

- Chairman: Workshop on Predicting Responses of Fish Populations to Acidification, Holiday Inn, Oak Ridge, Tennessee, May 1986.
- Participant: Second Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985; Peer Review Workshop on the Eastern Lake Survey Phase II Research Plan, Washington, D.C., November 1985; National Surface Water Survey, National Stream Survey, Mid-Atlantic Phase I and Southeast Screening Peer Review, Atlanta, Georgia, January 1986.
- Ad hoc reviewer: Hudson River Foundation; *Canadian Journal of Fisheries and Aquatic Sciences*.

CLAPP, R. B.

- Member: Soil Water Committee; American Geophysical Union.
- Participant: Southern Forestry Research and Environment Council, Broken Bow, Oklahoma, August 1986; West Valley Interagency Review Committee, West Valley, New York, November 1986.
- Advisor: Juanita Cherry, Science Teachers Research Involvement for Vital Education (STRIVE) Program, Teacher, Joelton Middle School, Joelton, Tennessee.
- Ad hoc reviewer: *Water Resources Research, Journal of Hydrological Processes*.

COOK, R. B.

- Member: Environmental Sciences Division Planning Group for Space-Based Environmental Research.
- Participant: Annual review of Electric Power Research Institute project on Ecological Effects of Acidification on Low-Order Woodland Streams, Washington, D.C., April 1986; Soil Weathering Workshop sponsored by Electric Power Research Institute and Environmental Protection Agency, Knoxville, Tennessee, May 1986; Gordon Conference on Environmental Chemistry: Water, New Hampton, New Hampshire, June 1986.
- Advisor: Coadvisor to Barbara W. Liukkonen, M.S. candidate, University of Minnesota, Duluth.
- Ad hoc reviewer: *Water, Air, and Soil Pollution, Environmental Science and Technology; American Chemical Society Symposium Series*.

COUTANT, C. C.

- Chairman:** Lake Anna Technical Advisory Committee, Virginia Water Control Board; Environmental Quality Advisory Board, City of Oak Ridge; ORNL/University of Tennessee Distinguished Lecturer Series (Cochairman); Tennessee Chapter of the American Fisheries Society (Program Chairman).
- Member:** Clinch River Monitored Retrieval Storage Task Force, City of Oak Ridge/Roane County; Oak Ridge Interagency Task Force; ORNL Wigner Fellowship Committee; ORNL General Energy Conservation Committee; ORNL/University of Tennessee Joint Life Sciences Committee; Environmental Sciences Division Scientific Achievement Award Committee.
- Participant:** Southern Division American Fisheries Society, Annual Meeting, Lexington, Kentucky, October 1985; Panel on Community Risk Information for the Public, Oak Ridge, Tennessee, November 1985; Forum on Creation and the Environment, First Methodist Church, Oak Ridge, Tennessee, January 1986; Tremont Environmental Education, Great Smoky Mountains National Park, Gatlinburg, Tennessee, May 1986; IV International Congress in Ecology, Syracuse, New York, August 1986; American Fisheries Society Annual Meeting, Providence, Rhode Island, September 1986.
- Faculty:** Adjunct Professor, University of Tennessee, and Tennessee Technological University, Cookeville.
- Advisor:** Denise Benson, M.S. candidate, University of Tennessee; Mark S. Bevelheimer, Ph.D. candidate, University of Tennessee.
- Ad hoc reviewer:** National Oceanic and Atmospheric Administration Oceans Assessment Division, International Association for Great Lakes Research, Texas Parks and Wildlife Department, Wisconsin Sea Grant College Program; *Transactions of the American Fisheries Society*, *Fresh Water Fishes of Virginia*, *Fishery Bulletin*, *Environmental Biology of Fishes*, *Proceedings Southeastern Association of Fish and Wildlife Agencies*, *Water Research*, *Journal of Freshwater Biology*.
- Other:** President-elect, Southern Division American Fisheries Society; Executive Committee, Water Quality Section, American Fisheries Society; Associate Editor, American Fisheries Society.

CUSHMAN, J. H.

- Member:** Oak Ridge National Laboratory Performance Improvement Process committee member for R&D subcontracting procedures; Tennessee Valley Authority Nonwoody Resource Assessment Task Force.

Advisor: Department of Energy's Great Lakes Region Program.

Ad hoc reviewer: Department of Energy's Small Business Innovation Research Program.

Other: President, Association for Women in Science, East Tennessee Chapter; guest lecturer, Educational Enrichment Workshop for Accelerated Children.

CUSHMAN, R. M.

Advisor: Susan L. Schuhardt, B.S. candidate, Northern Arizona University; Dennis B. Miller, M.Env.S., Miami University.

Ad hoc reviewer: *Transactions of the American Fisheries Society.*

CUTSHALL, N. H.

Participant: Conference on Groundwater Protection Policies for the Tennessee Valley and the Nation (chaired by Senator Albert Gore and sponsored by Environmental and Energy Study Institute and TVA), Nashville, Tennessee, October 1985; Department of Energy Information Meeting on the South Atlantic Bight Regional Marine Program, Skidaway Institute of Oceanography, Savannah, Georgia, October 1985; IAEA Research Coordination Meeting of the Coordinated Research Programme, Vienna, Austria, November 1985; meeting of the Oceanographic Subcommittee of the Interagency Nuclear Safety Review Panel for Project Galileo, Augusta, Georgia, December 1985; cochairman (with Dr. Donald Reish) of session on Cycling of Contaminants, 6th International Ocean Disposal Symposium, Pacific Grove, California, April 1986.

Ad hoc reviewer: DOE Small Business Innovation Research Program; National Science Foundation, Division of Ocean Sciences.

DALE, V. H.

Member: Environmental Quality Advisory Board, City of Oak Ridge.

Participant: International Union of Forest Research Organisations Conference, Knoxville, Tennessee, October 1985; Tennessee Valley Authority Second Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985; National Acid Precipitation Assessment Program Workshop on Forest Models, Charlottesville, Virginia, November 1985; Landscape Ecology Symposium, Athens, Georgia, January 1986; International Congress of Ecology and Ecological Society of America Meeting, Syracuse, New York, August 1986; Workshop on Array and Parallel Processing in Landscape Dynamics, Fort Collins, Colorado, September 1986.

Advisor: Advisor for Howard L. Watson, middle school teacher, sponsored by Science Teachers Research Involvement for Vital Education (STRIVE).

Ad hoc reviewer: *Ecology*.

DAVIS, E. C.

Member: Review team for Department of Energy/Oak Ridge Operations legal staff preparing Fernald, Ohio, litigation.

Participant: ORNL Radiochemistry Training Program, Oak Ridge National Laboratory, September–October 1986.

Advisor: Linda R. Bauer, M.S. candidate, Purdue University.

DeANGELIS, D. L.

Member: Northern Lakes Long-Term Ecological Reserve (LTER) Site Review Panel; Environmental Sciences Division Achievement Award Committee.

Faculty: Adjunct faculty, University of Tennessee.

Advisor: Anthony W. King, Ph.D. candidate, University of Tennessee; Joyce C. Waterhouse, Ph.D. candidate, University of Tennessee.

Ad hoc reviewer: *Ecological Modelling, Environmental Biology of Fishes, Proceedings of the Soil Science Society of America, American Naturalist, Journal of Mathematical Analysis and Applications, Canadian Journal of Fisheries and Aquatic Sciences*; proposals: NSF.

DREIER, R. B.

Participant: Alabama Geological Society field trip, Sylacauga, Alabama, November 1985; Northeastern Geological Society of America field trip, Kiamesha Lake, New York, March 1986; American Association of Petroleum Geologists Fractured Reservoir Analysis short course, Great Falls, Montana, August 1986.

Faculty: Adjunct Assistant Professor, University of Tennessee.

Advisor: Anne I. Scales, M.S. candidate, University of Tennessee; Cathy M. Beaudoin, B.S. candidate, Beloit College; Ginny L. Gray, B.S. candidate, Austin Peay College; Joe Paul (final editing of M.S. thesis), University of Tennessee.

Other: Cochairman, Environmental Sciences Division United Way Campaign, 1986.

EDDLEMON, G. K.

- Member:** Town of Farragut Hydrology Committee.
- Participant:** Sixth National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D.C., November 1985; Environmental Audits Course, Arlington, Virginia, June 1986; preparation of Draft Environmental and Occupational Safety Manual for Naval Inactive Ship Maintenance Facilities (July 1986); Draft Environmental Survey Manual for Department of Energy facilities; Preliminary Draft Environmental Assessment for Renewal of Source Material License, Columbium-Tantalum Division of Mallinckrodt, Inc.; Draft Environmental Assessment for Williston Military Operations Area; Final Environmental Assessment for Proposed Air Force Bombing Routes IR-140 and IR-128; Final Environmental Assessment for Proposed Air Force Low Level Training Route IR-607.

EDWARDS, N. T.

- Participant:** Ninth International Symposium on Polynuclear Aromatic Hydrocarbons, Battelle, Columbus, Ohio, October–November 1985.
- Ad hoc reviewer:** *Forest Science, Pedobiologia, Journal of Environmental Quality, Ecology*; proposals: NSF, DOE, EPA.

ELWOOD, J. W.

- Chairman:** Annual review of Electric Power Research Institute project on the Ecological Effects of Acidification on Low-Order Woodland Streams, Washington, D.C., April 1986.
- Member:** Advisory Panel, Ecosystem Studies Program, Division of Biotic Systems and Resources, National Science Foundation.
- Participant:** Workshops on Watershed Biogeochemistry, Oak Ridge National Laboratory, July 1986.
- Faculty:** Adjunct Professor, Graduate Program in Ecology, University of Tennessee, and Adjunct Faculty Member, Graduate Ecology Program, University of North Carolina, Chapel Hill.
- Advisor:** Julie Segars, M.S. candidate, University of Tennessee; Amy D. Rosemond, M.S. candidate, University of North Carolina, Chapel Hill; Byron S. Geerlings, B.S. candidate, Birmingham-Southern College, Birmingham, Alabama.
- Ad hoc reviewer:** *Biogeochemistry, Canadian Journal of Fisheries and Aquatic Science, Journal of the North American Benthological Society, Limnology and Oceanography, Journal of the American Water Works Association*; proposals: EPA, EPRI, and NSF.

EMANUEL, W. R.

Member: Environmental Sciences Division Graduate Student Selection Committee; Working Groups on Land, Processes and Earth System Modeling, NASA-Earth System Sciences Committee.

Ad hoc reviewer: *Tellus, Journal of Geophysical Research*; International Institute for Applied Systems Analysis (IIASA) reports; NSF and NASA proposals.

FRANCIS, C. W.

Ad hoc reviewer: *Environmental Science and Technology, Environmental Experimental Botany*; DOE proposals.

GARDNER, R. H.

Member: Review of International Institute of Applied Systems Analysis Program on Uncertainty Analysis, Laxenburg, Austria, April 1986; Buell Award Selection Committee, 1986, at Annual Meeting of the Ecological Society of America, Syracuse, New York, August 1986.

Participant: Gordon Research Conference on Fractals, August 1986; 12th Annual Scientific Research Meeting, Great Smoky Mountains National Park, Gatlinburg, Tennessee, May 1986; Symposium on the Role of Landscape Heterogeneity in the Spread of Disturbance, University of Georgia, Athens, January 1986; Workshop on Array and Parallel Processing in Landscape Dynamics, Pingree Park, Colorado, September 1986; IV International Congress of Ecology, Syracuse University, Syracuse, New York, August 1986.

Faculty: Adjunct Professor, University of Tennessee.

Consultant: International Atomic Energy Agency, Vienna, April 1986; International Institute of Applied Systems Analysis, June-July 1986.

Ad hoc reviewer: *Water Resources Research*; International Atomic Energy Agency.

Other: Charter member, U.S. Chapter of the International Association for Landscape Ecology; Environmental Sciences Division Scientific Achievement Award, 1985.

GARTEN, C. T.

Participant: Sixth Annual Meeting of the Society of Environmental Toxicology and Chemistry, St. Louis, Missouri, November 1985; Behavior of Technetium in Terrestrial and Aquatic Environments, Workshop on Research Status and Needs, Seattle, Washington, May 1986 (session chairman).

Advisor: J. Henrot, Ph.D. candidate, University of Tennessee.

Ad hoc reviewer: NSF proposal.

GRAHAM, R. L.

Member: International Union of Forest Research Organisations Working Group (PNW S1.02.09) on Management Impacts on Forest Productivity, served as FORCYTE model users discussion facilitator, organized FORCYTE discussion at annual working meeting, January 1986, Olympia, Washington; International Energy Agency/Forestry Energy project, The Nutritional Consequences of Intensive Forest Harvesting on Site Productivity: served as Weyerhaeuser Company's representative to project, and provided evaluation of productivity models.

Participant: International Union of Forest Research Organisations Whole Plant Physiology Symposium, Knoxville, Tennessee, October 1985; IV International Congress of Ecology, Syracuse, New York, August 1986.

HAASE, C. S.

Member: Geochemistry and Modeling Subcommittee of the Research Committee of the Underground Injection Practices Council.

Faculty: Adjunct Assistant Professor, University of Tennessee.

Advisor: C. M. Lutz, Ph.D. candidate, University of Tennessee; J. Weber, Ph.D. candidate, University of Tennessee.

HERBES, S. E.

Chairman: Environmental Sciences Division Education Committee.

Member: West Valley Interagency Technical Advisory Committee on Low-Level Waste Disposal; Executive Committee, University of Tennessee Ecology Program; Performance Improvement Program (PIP) Team investigating hazardous waste reduction in Environmental Sciences Division.

Faculty: Adjunct Associate Professor, University of Tennessee.

Advisor: C. Dean Little, Ph.D. candidate, Florida State University, Scott B. Redman, M.S. candidate, Indiana University.

Ad hoc reviewer: *Environmental Science and Technology*; DOE Small Business Incentive Program.

Other: Facilitator, ORNL Career Planning Program.

HILDEBRAND, S. G.

Member: National Research Council Ad Hoc Panel on Impacts of Large Dams; Department of Energy/Electric Power Research Institute Hydroelectric Technology Transfer Committee; International Hydrological Programme Project Team on Energy Policies and Strategies for Water Resource Development.

Participant: Fourth International Congress of Ecology, Syracuse, New York, August 1986; 1986 Annual Meeting of National Acid Precipitation Assessment Program, Greenbelt, Maryland, June 1986; Symposium on Landscape Ecology, Athens, Georgia, January 1986.

Faculty: Faculty Associate, University of Tennessee.

Ad hoc reviewer: NSF proposals.

HOFFMAN, F. O.

Chairman: Session Chairman and organizer for 1st BIOMOVs workshop: Testing of Mathematical Models that Predict the Accumulation and Remobilization of Radionuclides and Other Trace Substances in the Biosphere [National Institute of Radiation Protection (NIRP) scientific consultant and U.S.A. representative], Baden Switzerland, October 1985; General Chairman for International Atomic Energy Agency Technical Advisory Meeting on Methods for Evaluating the Reliability of the Predictions of Environmental Models, Vienna, Austria, November 1985; Session Chairman for NIRP Workshop on International Biospheric Model Validation, Paris, France, February 1986; Session Chairman and organizer for Commission of the European Communities/Department of Energy-cosponsored Symposium on the Behavior of Technetium in Terrestrial and Aquatic Environs, Seattle, Washington, May 1986; Chairman for International Atomic Energy Agency Consultants Meeting on Evaluation of the Reliability of Model Predictions, Vienna, Austria, March 1986; International Atomic Energy Agency Consultants Meeting on Environmental Transfer Coefficients and Applications to Developing Countries, Carmel, California, June 1986; and Department of Energy/Office of Health and Environmental Health Workshop on the Validation and Testing of Food Chain Transfer Models, Department of Energy Headquarters, Germantown, Maryland, April 1986.

Member: Scientific Committee 64, Task Group 6, of the National Council of Radiation Protection and Measurements; Oak Ridge Task Force, Task Group V, Environmental Health and Risk Analysis; and International Union of Radioecologists (candidate for board of directors).

Advisor: Eliana C. Amaral, Institute of Radiation Protection and Dosimetry, Department of Environmental Radiological Protection, Rio de Janeiro, Brazil, and International Atomic Energy Agency, Vienna.

Consultant: International Atomic Energy Agency, Vienna, Model Reliability Analysis; International Atomic Energy Agency, Vienna, Evaluation of Environmental Transfer Coefficients; Swedish National Institute for Radiation Protection, BIOMOVs project.

HUFF, D. D.

- Member:** Environmental Sciences Division Scientific Achievement Award Committee.
- Participant:** ORNL Project Management Training, October 1985, Oak Ridge, Tennessee.
- Faculty:** Adjunct Associate Professor, University of Tennessee.
- Consultant:** Civil Engineering Department, University of Tennessee.
- Ad hoc reviewer:** DOE Small Business Innovation Research Program; U.S. Geological Survey Interpretive Hydrologic Reports.

HUNSAKER, C. T.

- Chairman:** Vice-Chairman, Ecology Committee, Water Pollution Control Federation.
- Member:** Marine Water Quality Committee and Program Committee, Water Pollution Control Federation; Environmental Sciences Division Education Committee.
- Participant:** Follow-up/Audit of Environmental Results, October 1985, Banff Centre, Banff, Canada; 58th Annual Water Pollution Control Federation Conference, October 1985, Kansas City, Missouri; ORNL classes on Managing Conflict, November 1985, and Oral Technical Presentation Design, May 1986; STORET training course, August 1986, ORNL; Power Communication Skills for Women, September 1986, Knoxville.
- Advisor:** Nancy J. Lambert, B.S. candidate, Grinnell College.
- Ad hoc reviewer:** *Journal of the Water Pollution Control Federation, The Environmental Professional*; 1985 National Acid Precipitation Assessment Program Annual Report; Rock Creek Watershed, Tennessee Petition Evaluation Document/ Environmental Impact Statement (draft).
- Other:** Editorial Board for *The Environmental Professional*; Sigma Xi Centennial Planning Committee; membership chairperson, Association for Women in Science, East Tennessee Chapter; Environmental Sciences Division undergraduate student advisor; Oak Ridge Associated Universities Traveling Lecture Program.

HUSTON, M. A.

- Chairman:** Ecological Society of America Symposium on Ecosystem and Community Implications of Population Models, Ecological Society of America/International Congress of Ecology (ESA/INTECOL) meetings, Syracuse, New York, August 1986.
- Participant:** Workshop for preparation of Costa Rica Long-Term Ecological Research proposal, University of Florida, Gainesville, August 1986.

Faculty: Adjunct Associate Professor, University of Tennessee; lecturer, Woods Hole Marine Biological Laboratory, Graduate Course in Marine Ecology, July 1986 (invited).

Ad hoc reviewer: *Ecology, American Naturalist, Conservation Biology, Biotropica.*

JACOBS, G. K.

Chairman: ORNL/Nuclear Regulatory Commission Workshop: Radionuclide Sorption Modeling Related to High-Level Nuclear Waste Repository Performance Assessment, Silver Spring, Maryland, May 1986.

Member: Environmental Sciences Division Computer Advisory Committee; Environmental Sciences Division Seminar Committee; Chemical Thermodynamics Advisory Committee.

Participant: Geological Society of America Annual Meeting, Orlando, Florida, October 1985; NRC Workshop on the Validation of Mathematical Models for Waste Repository Performance Assessment, Bethesda, Maryland, January 1986; EQ3/6 Geochemical Model Workshop, Oak Ridge, Tennessee, July 1986; American Chemical Society National Meeting, Anaheim, California, September 1986.

Ad hoc reviewer: *Nuclear Safety*; American Chemical Society Petroleum Research Fund.

JIMENEZ, B. D.

Member: Proposal Review Committee for the National Research Council on the selection of Ford Foundation Fellows; 1985 Ford Foundation Conference Planning Committee of the National Research Council.

Participant: Life Sciences presentation session of the 1985 Ford Foundation Conference, Washington, D.C., November 1985; Environmental Protection Agency Workshop on Finfish as Indicators of Toxic Contamination in Estuaries, Airlie, Virginia, July 1986.

Advisor: Lisa S. Burtis, M.S. candidate, University of Tennessee; Susan D. Meads, B.S. candidate, Birmingham-Southern College; and Gabriela Cacheiro, B.A. candidate, University of Tennessee.

JOHNSON, D. W.

Member: Oversight Committee, Environmental Protection Agency Watershed Manipulation Project; Advisory Panel, Eastern Brooks Watershed Study Peer Review Panel; Florida Acid Deposition Study Fertilization Committee; International Union of Forest Research Organisations.

Faculty: Adjunct Professor, College of Forestry, Fisheries, and Wildlife, University of Tennessee.

Ad hoc reviewer: Journals of Soil Science Society of America, *Journal of Environmental Quality*, *Biogeochemistry*, *Water, Air, and Soil Pollution*; NSF and USDA proposals.

Other: Associate Editor, *Journal of Environmental Quality*.

JOHNSTON, J. W.

Member: Selection Committee for Monoculture Viability Trial proposals.

Ad hoc reviewer: *Risk Analysis Journal*; proposals: USDA Competitive Research Grants Office.

KIMMEL, B. L.

Member: Editorial Board, Lake and Reservoir Management, North American Lake Management Society; Project Team, Lake Restoration Guidance Manual, North American Lake Management Society.

Participant: Cyanophyte Dominance and Water Quality Symposium, University of Oklahoma, Norman, March 1986; North American Lake Management Society Annual Meeting, and International Symposium on Lake and Reservoir Management, Portland, Oregon, October 1985.

Faculty: Adjunct Assistant Professor, Department of Zoology, University of Oklahoma, Norman; Faculty Associate, Graduate Program in Ecology, University of Tennessee.

Advisor: ORNL-Environmental Sciences Division primary research advisor and cochairman of Ph.D. advisory committee: Alan W. Groeger, Ph.D. candidate, University of Oklahoma; graduate committee member: Tina Johnson, M.S. candidate, University of Tennessee; Clell Ford, M.S. candidate, University of Tennessee; Mary Evans Culver, M.S. candidate, University of Tennessee.

Ad hoc reviewer: *Ecology*, *Ecological Monographs*, *Journal of the American Water Works Association*, *The Southwestern Naturalist*, *Lake and Reservoir Management*, *Journal of Freshwater Ecology*, *Journal of the Tennessee Academy of Sciences*; NSF and DOE/ERD proposals.

KROODSMA, R. L.

Member: Oak Ridge Reservation Resource Management Organization.

Participant: Preparation of environmental assessments for Air Force Low Level Flight Route IR-607, Air Force Bombing Competition Route IR-140/428, and Air Force Williston Military Operations Area Subsonic Operations; Final Environmental Impact Statement for Winnersville Weapons Range; assessment of the public health impacts from the accidental release of

UF₆ at the Sequoyah Fuels Corporation facility at Gore, Oklahoma; reviews of environmental monitoring plans submitted to the Synthetic Fuels Corporation.

LARSEN, I. L.

Ad hoc reviewer: DOE Small Business Innovation Research Program.

LAYTON, P. A.

Chairman: Forest Resources Committee, Southeastern Regional Biomass Program, Task Force Meeting, Atlanta, Georgia, February 1986; Program Review, July 1986.

Participant: International Energy Agency Task II Activity Workshop, Forest Crop Nutrition: Production, Prices, and Pathways, Kingston, Ontario, May 1986; Society of American Foresters North American Forest Biology Workshop, Oklahoma State University, June 1986; International Union of Forest Resource Organisations Symposium on Whole Tree Physiology, Knoxville, Tennessee, October 1985.

Faculty: Lecturer in Biomedical Sciences, Graduate School of Biomedical Sciences, University of Tennessee.

Ad hoc reviewer: Proposals: New York State Energy Research Development Agency, DOE Small Business Innovation Research Program, Great Lakes Regional Biomass Program, U.S. Department of Agriculture Competitive Research Grants.

LEE, S. Y.

Member: Southern Regional Clay Mineralogy Work Group, Technical Committee S-152, U.S. Department of Agriculture.

Participant: Southern Regional Clay Mineralogy Work Group, Technical Committee S-152 meeting, Raleigh, North Carolina, May 1986; invited speaker, Soil Science Society of Korea meeting, Teagu, Korea, July 1986; Nevada Test Site Work Group meeting, Las Vegas, Nevada, September 1986.

Faculty: Adjunct Associate Professor, University of Tennessee.

Advisor: D. H. Phillips, M.S. candidate, University of Tennessee; R. E. Lambert, M.S. candidate, University of Tennessee.

Ad hoc reviewer: *Soil Science, Soil Science Society of America Journal, Clays and Clay Minerals, Journal of Environmental Quality, Nuclear and Chemical Waste Management.*

Other: President of Tennessee Chapter of The Korean Scientists and Engineers Association in America.

LINDBERG, S. E.

- Chairman: Technical Committee, International Conference on Heavy Metals in the Environment; Organizing Committee, National Acid Precipitation Assessment Program Workshop on Dry Deposition Methodology; Panel on Atmosphere/Canopy Interactions, Department of Energy Workshop on Atmospheric Chemistry.
- Member: Editorial Board, *Advances in Environmental Science*; Executive Committee, National Atmospheric Deposition Program; Mercury Working Group, United Nations Scientific Committee on Problems in the Environment; Organizing Committee, International Conference on Environmental Chemistry; MAP3S/RAINE Precipitation Chemistry Network; review team, Eastern Brook Lakes Watershed Study.
- Participant: North Atlantic Treaty Organisation Advanced Workshop on Deposition to Mountainous Terrain, Edinburgh, Scotland, September 1986; National Atmospheric Deposition Program Annual Meeting, Fort Collins, Colorado, October 1985; Workshop on Measuring Trace Metals in Rain, Toronto, Canada, January 1986; National Acid Precipitation Assessment Program Workshop on Dry Deposition Methodology, Harpers Ferry, West Virginia, March 1986.
- Advisor: Chris Potter, Ph.D. candidate, Emory University; Will Petty, summer student, Grinnell College.
- Ad hoc reviewer: Springer Verlag; John Wiley & Sons; proposals: NSF, University of Kansas, DOE, EPRI, USDA, National Research Council of Canada; *Canadian Journal of Forest Research*, *Biogeochemistry*, *Water, Air, Soil Pollution*, *Health Physics*, *Environmental Science and Technology*, *Science*, *Atmospheric Environment*, *Journal of Geophysical Research*, *Journal of Environmental Quality*, *Journal of the Air Pollution Control Association*.
- Other: Secretary and Chairman-elect, National Atmospheric Deposition Program.

LOAR, J. M.

- Chairman: Work Group on Aquatic Habitats, Oak Ridge Reservation Resource Management Committee.
- Member: Fishery Study Group, Oak Ridge Task Force.

LUXMOORE, R. J.

- Chairman: International Union of Forest Research Organisations Working Party on Whole-Plant Physiology.

- Member:** American Registry of Certified Professionals in Agronomy, Crops and Soils; Regional Technical Committee (S-185) on Spatial and Temporal Variability of Soil Characteristics and Material Fluxes in Field Soils; review panel for the National Forest Response Research Program's Southern Commercial Forest Research Cooperative, March 1986, Raleigh, North Carolina; review panel for the National Acid Precipitation Assessment Program's Watershed Manipulation Project Research Plan, June 1986, Atlanta, Georgia.
- Participant:** XIII Congress of the International Society of Soil Science, Hamburg, Federal Republic of Germany, August 1986; 18th International Union of Forest Research Organisations World Congress, Ljubljana, Yugoslavia, September 1986.
- Faculty:** Faculty Associate, Plant Physiology and Genetics Program, Life Sciences Graduate Program, University of Tennessee.
- Ad hoc reviewer:** *Pedobiologia*, *Soil Science Society of America Journal*, *Tree Physiology*; proposals: DOE, U.S. Forest Service, USDA.
- Other:** Host for IUFRO Symposium on Coupling of Carbon, Water and Nutrient Interactions in Woody Plant Soil Systems, Knoxville, Tennessee, October 1985; Associate Editor for *Soil Science Society of America Journal* and *Tree Physiology*.

MANN, L. K.

- Participant:** International Congress of Ecology/Ecological Society of America meeting, Syracuse, New York, August 1986.
- Ad hoc reviewer:** *Canadian Journal of Forest Research*.

McBRAYER, J. F.

- Participant:** Environmental Protection Agency Superfund Innovative Technology Evaluation Program Meeting, Edison, New Jersey, February 1986; Waste Management 1986, Tucson, Arizona, March 1986; session chairman, HazMat '86, Atlantic City, New Jersey, June 1986; Department of Energy Defense Waste and Transportation Management Lead Site Program Interface Meeting, Denver, Colorado, June 1986; Department of Energy Hazardous Waste Technical Review Group, Augusta, Georgia, January 1986; Department of Energy Hazardous Waste Technical Review Group, Oak Ridge, Tennessee, May 1986; Department of Energy Hazardous Waste Technical Review Group, Alexandria, Virginia, July 1986; U.S. Air Force Systems Command Environmental Coordinators' Installation Restoration Program Workshop, Cocoa Beach, Florida, September 1986.

McCARTHY, J. F.

- Member: Panel on the Role of Humics in Contaminant Transport and Fate, National Research Council.
- Participant: Committee on Biological Markers, National Research Council; Army Corps of Engineers Workshop on Regulation and Identification of Petroleum Hydrocarbons in Sediment, Vicksburg, Mississippi, May 1986.
- Advisor: M. C. Black, Ph.D. candidate, University of Tennessee; L. J. Shepard, M.S. candidate, Indiana University; L. A. Woodward, Ph.D. candidate, University of Tennessee; W. D. Burton, Ph.D. candidate, University of Tennessee; Secondary Advisor to S. S. Talmage, Ph.D. candidate, University of Tennessee; M. T. Kay, Great Lakes College Association; D. Jacobson, B.S. candidate, Florida State University.
- Ad hoc reviewer: *Environmental Science and Technology, Aquatic Toxicology, Archives of Environmental Contamination and Toxicology, Journal of Environmental Quality, Environmental Pollution*; DOE proposals.

McLAUGHLIN, S. B.

- Faculty: Adjunct Professor, University of Tennessee.
- Advisor: A. Stam, Ph.D. candidate, University of Tennessee; T. Leininger, Ph.D. candidate, Virginia Polytechnic Institute and State University.

MILLEMANN, R. E.

- Faculty: Adjunct Professor, University of Tennessee.

MULHOLLAND, P. J.

- Chairman: Environmental Sciences Division Seminar Committee.
- Ad hoc reviewer: Proposals: NSF and The Hudson River Foundation; *Ecology, Journal of the North American Benthological Society*.

NORBY, R. J.

- Participant: Symposium Operations Committee for the International Union of Forest Research Organisations (IUFRO) Symposium on Whole-Plant Physiology, Knoxville, Tennessee, October 1985; Spruce-Fir Research Planning Workshop II, U.S. Forest Service, Philadelphia, January 1986; IUFRO Workshop, Techniques and Approaches in Forest Tree Ecophysiology, Ithaca, New York, August 1986.
- Advisor: Thelberstine Barbee, M.S. candidate, Tuskegee Institute; Betsy Batchelor, Oak Ridge High School.
- Ad hoc reviewer: *Tree Physiology, Journal of Environmental Quality*; U.S. Forest Service; proposals: DOE Short Rotation Woody Crops Program.

OLSEN, C. R.

Participant: Department of Energy Southeast Marine Program SPREX (Spring Runoff Experiment) Workshop, Athens, Georgia, April 1986; Session Chairman, Geochemical Tracers, Department of Energy Workshop on Future Research in the Savannah Estuary and Southeastern Atlantic Shelf, Skidaway Institute of Oceanography, Savannah, Georgia, October 1986.

Ad hoc reviewer: *Health Physics, Journal of Geophysical Research—Oceans*; proposals: National Oceanic and Atmospheric Administration National Sea Grant College Program and The Hudson River Foundation.

OLSON, R. J.

Participant: Fifth Annual Conference and International Symposium on Applied Lake and Watershed Management, Lake Geneva, Wisconsin, November 1985; Assessment Planning Workshop, National Acid Precipitation Assessment Program, Coolfont, West Virginia, November 1985; Workshop on Geographic Information Systems for Environmental Protection, Environmental Protection Agency, Las Vegas, Nevada, January 1986; Experimental Design and Data Management Quality Assurance Methods Manual Development Workshop (Co-Group Leader), Environmental Protection Agency, Raleigh, North Carolina, March 1986; Internationally Compatible Environmental Data, a CODATA Workshop (session recorder), CODATA, Montreal, Quebec, May 1986; National Acid Precipitation Assessment Program 1986 Annual Meeting, Greenbelt, Maryland, June 1986; Environmental Trends Indicators Meeting, Council on Environmental Quality, Washington, D.C., June 1986; Tenth International CODATA Conference, Ottawa, July 1986; Need of a National Biological Survey Meeting, President's Commission on Americans Outdoors, Washington, D.C., July 1986.

Ad hoc reviewer: Technologies to Maintain Biological Diversity, Office of Technology Assessment.

Other: Witness: Acid Rain Investigative Hearings organized by Congressman D. R. Obey, July 1986, Rhinelander and Stevens Point, Wisconsin.

O'NEILL, R. V.

Member: National Academy of Sciences Committee on Planetary Biology; Advisory Committee, Department of Energy Office of Health and Environmental Research Arctic Ecosystems Program; Advisory Committee, Niwott Ridge National Science Foundation Long-Term Ecological Reserve (NSF-LTER) Program; Advisory Committee, Grasslands NSF-LTER Program; Advisory Committee, Northern Lakes NSF-LTER Program; Martin Marietta Publication Awards Committee; Performance Improvement Program Committee on Document Review Procedures.

- Participant:** Scientific Committee on Problems of the Environment (SCOPE) International Meeting on Global Change; Department of Energy Biomedical and Environmental Seminar Series; Ecological Society of America Symposium on Network Theory; Ecological Society of America Symposium on Modeling Complex Systems.
- Faculty:** Adjunct Professor, Ecology Program, University of Tennessee; seminar course on Hierarchy Theory, University of Tennessee.
- Advisor:** Dean Urban, Ph.D. candidate, University of Tennessee; Anthony King, Ph.D. candidate, University of Tennessee.
- Ad hoc reviewer:** Proposals: Ecology Program, NSF; Ecosystem Studies Program, NSF; Global Ecology Program, NASA; DOE-OHER; *Environmental Management*, *American Naturalist*; Prentice-Hall, Columbia University Press, SCOPE.

PALUMBO, A. V.

- Participant:** Second Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985; 86th Annual Meeting of American Society for Microbiology, Washington, D.C., March 1986; Joint American Society for Microbiology—Canadian Society of Microbiology Symposium on Environmental Insult and Recovery of Stressed Systems, Toronto, Canada, June 1986; Electric Power Research Institute stream study, Washington, D.C., April 1986; Second Investigators Meeting, Department of Energy/Savannah River Laboratory Subsurface Microbiology Program, Germantown, Maryland, September 1986.
- Faculty:** Research Associate, University of Tennessee; guest lecturer for course in Limnology, University of Tennessee.

PARR, P. D.

- Chairman:** National Environmental Research Park Group for Department of Energy—Oak Ridge Reservation Resource Management Committee.
- Member:** Subcommittee to Review the Cost/Benefits of the Forest Management Program; Task Group to Review the Barrier/Lock System on the Oak Ridge Reservation; Task Group to Review the Oak Ridge National Environmental Research Park; Environmental Sciences Division Awards Committee; ORNL/Oak Ridge Associated Universities Pre-College Science Education Advisory Committee.
- Participant:** Plant Conservation Strategies: Options for the Future, Lakeland College, Mentor, Ohio, May 1986; 12th Annual Scientific Research Meeting,

Great Smoky Mountains National Park, May 1986; Biosphere Reserve Meeting for current and potential members of the Southern Appalachian Highland Cluster Group, Great Smoky Mountains National Park, December 1985; Annual Meeting of Association of Southeastern Ecologists, Columbia, South Carolina, April 1986; Annual Meeting of Ecological Society of America, Syracuse, New York, August 1986.

Advisor: Larry R. Pounds, Ph.D. candidate, University of Tennessee; Katie Greenberg, M.S. candidate, University of Tennessee.

Other: Summer student: Rhonda K. Jones, Undergraduate, Fort Valley State College, Georgia; fall student: Wendy Sera, Undergraduate, Earlham College, Indiana.

PENG, T.-H.

Participant: Ocean Sciences Meeting of American Geophysical Union and American Society of Limnology and Oceanography, New Orleans, Louisiana, January 1986; American Geophysical Union Spring Meeting, Baltimore, Maryland, May 1986; Symposium on Marine Sciences, Institute of Marine Sciences, National Sun Yat-sen University, Kaohsiung, Taiwan, Republic of China, August 1986.

Ad hoc reviewer: National Science Foundation (marine chemistry, polar studies); Department of Energy (carbon dioxide research); Natural Environment Research Council, United Kingdom; *Journal of Geophysical Research*, *Earth and Planetary Sciences Letter*, *Science*, *Nature*, *Deep-Sea Research*.

POST, W. M.

Faculty: Associate Professor, University of Tennessee.

Ad hoc reviewer: *American Naturalist*, *Theoretical Population Biology*; ORNL Global Carbon Cycle Program.

RANNEY, J. W.

Member: Technical Association of the Pulp and Paper Industry.

Participant: American Association for the Advancement of Science/Society of American Foresters representative on silviculture to the India National Science Academy and Indian Environment Ministry; Society of American Foresters intermediary participant on U.S. Department of Agriculture-Forest Service national forest management plans; session chairman on Biotechnology, 1986 Technical Association of the Pulp and Paper Industry R&D Conference; session chairman on Silviculture, 1986 Southern Forest Biomass Workshop.

Advisor: Registered on Forestry Support Group (U.S. Department of Agriculture Forest Service) for the U.S. Agency for International Development; Technical Steering Committee, Department of Energy Regional Program for the Great Lakes Region.

Ad hoc reviewer: U.S. Agency for International Development; *Forest Science*; DOE Small Business Innovation Research Program.

REED, R. M.

Member: Executive Committee, Graduate Program in Ecology, University of Tennessee.

Participant: U.S. Air Force Final Environmental Assessment, Proposed Low Level Training Route IR-276/276A, Arizona, Utah, and New Mexico; Draft Regulatory Guide, Nuclear Regulatory Commission, Standard Format and Contents of Environmental Reports for the License Renewal of Fuel Fabrication and UF₆ Conversion Facilities.

Faculty: Faculty Associate, University of Tennessee.

REICHLE, D. E.

Member: National Board of Governors, The Nature Conservancy; Chairman, Public Affairs Committee, Ecological Society of America; Governing Council, Ecological Society of America; Executive Council, Association of Ecosystem Research Centers; Biology Review Panel, Environmental Protection Agency; Environmental Advisory Group, Gas Research Institute; Policy Committee, Center for Environmental Biotechnology, The University of Tennessee; Board of Visitors, Indiana University School of Public and Environmental Affairs; Sigma Xi; Ecological Society of America; American Association for the Advancement of Science; Association of Southeastern Biologists; Tennessee Conservation Foundation; International Association for Ecology (INTECOL).

Participant: Employee Performance Evaluation Committee, Martin Marietta Energy Systems, Inc.; Special Awards Program, 37th International Science and Engineering Fair, Department of Energy.

Faculty: Adjunct Professor, University of Tennessee.

Ad hoc reviewer: *Ecology*, *Pedobiologia*, *Science*; Springer-Verlag; proposals: DOE, NSF.

Other: Editorial Board, *Pedobiologia*; Series Editor, Advanced Texts in the Life Sciences, Springer-Verlag.

ROSEN, A. E.

Participant: Statistical Analysis System Users Group International Conference, Atlanta, Georgia, February 1986; STORET Users Conference, Leesburg, Virginia, May 1986; STORET Training Seminar, Oak Ridge National Laboratory, August 1986.

SALE, M. J.

- Chairman:** Computer Advisory Committee, Environmental Sciences Division, Oak Ridge National Laboratory.
- Member:** Technical Advisory Committee for Pacific Gas and Electric Company on research related to instream flow needs below hydroelectric projects; Technical Advisory Committee for the U.S. Forest Service, Southern Timber Supply Study, to assist in the development of a predictive model to manage fishery resources affected by land management actions.
- Advisor:** G. M. Kondolf, Ph.D. candidate, The Johns Hopkins University.
- Ad hoc reviewer:** *Transactions of the American Fisheries Society, Canadian Journal of Fisheries and Aquatic Sciences, Water Resources Bulletin.*

SALK, M. S.

- Participant:** Energy from Biomass and Wastes X, Washington, D.C., April 1986; preparation of Solar Energy Research Institute Alcohol Fuels Assessment; ORNL review of public comments on the Department of Energy Draft Area Recommendation Report for a High-Level Radioactive Waste Repository in Crystalline Rock; preparation of comments on Environmental Protection Agency's Proposed Hazardous Waste Management System Rule: Companion rule to the first codification rule.
- Ad hoc reviewer:** Proposals: Energy Policy Development and Conservation Project, Agency for International Development (AID).

SHARPLES, F. E.

- Member:** Recombinant DNA Advisory Committee, National Institutes of Health, January and September 1986.
- Participant:** CERCLA/Superfund Law and Regulations, Government Institutes training course, Rosslyn, Virginia, October 1985; RCRA Regulations course, Government Institutes training course, Rosslyn, Virginia, October 1986; Environmental Laws and Regulations '86 update course, Government Institutes training course, Arlington, Virginia, April 1986; RCRA 1986, Hazardous Waste Treatment Council course, Alexandria, Virginia, May 1986; Hazardous Materials Transportation, Unz and Company seminar, Atlanta, Georgia, August 1986; HazMat '86, Fourth Annual Hazardous Materials Management Conference/Exhibition, Atlantic City, June 1986; IVth International Congress of Ecology/Ecological Society of America Annual Meeting, Syracuse, New York, August 1986.
- Consultant:** Working Group on Genetic Engineering and Biotechnology Safety, United Nations Environment Program, Nairobi, Kenya.

Ad hoc reviewer: *Science, BioScience, Technology and Human Values*; Cloning and the Constitution: An Inquiry into Governmental Policymaking and Genetic Experimentation, University of Wisconsin Press.

Other: Member, Public Affairs Committee, Ecological Society of America; member, Awards Committee, Association for Women in Science, East Tennessee Chapter; Tennessee representative, Public Responsibilities Network, American Institute of Biological Sciences.

SHRINER, D. S.

Member: Technical Council, Ecological Effects Committee, Air Pollution Control Association; Task Group V, Terrestrial Effects, National Acid Precipitation Assessment Program; Executive Committee (Past Chairman), National Atmospheric Deposition Program; Budget Advisory Committee, National Atmospheric Deposition Program; Science Advisory Panel, Eastern Hardwoods Research Cooperative (Senior Technical Advisor), U.S. Forest Service.

Participant: National Atmospheric Deposition Program Annual Meeting, Fort Collins, Colorado, October 1985; U.S. Forest Service Workshop on Eastern Hardwood Forest Decline, Philadelphia, Pennsylvania, January 1986; WATtec Conference, Knoxville, Tennessee, February 1986; National Acid Precipitation Assessment Program Fourth Annual Meeting, Greenbelt, Maryland, May 1986; National Air Pollution Workshop, Chicago, Illinois, April 1986.

Faculty: Adjunct Professor, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Advisor: D. E. Carpenter, D.Env. candidate, University of California, Los Angeles.

Ad hoc reviewer: *Science, Journal of the Air Pollution Control Association, Journal of Environmental Quality, Environmental and Experimental Botany, Water, Air, and Soil Pollution, Canadian Journal of Forest Research*; proposals: DOE, EPA, EPRI, and USDA.

SHUGART, L. R.

Member: Advisory Committee, Oak Ridge Graduate School of Biomedical Sciences, University of Tennessee/Biology Division; Ph.D. qualifying exam committee in biochemistry, Graduate School of Biomedical Sciences, University of Tennessee/Biology Division.

Advisor: Windel Stracener, B.S. candidate, Earlham College; Jeff Daniels, B.S. candidate, Birmingham-Southern College; Dan Jacobson, B.S. candidate, Florida State University; S. S. Talmage, Ph.D. candidate, University of Tennessee; Les Recio, Ph.D. candidate, University of Kentucky; Clinton Dixon, summer faculty participant, Fort Valley State College, Fort Valley, Georgia.

- Ad hoc reviewer: *Environmental Science and Technology, Aquatic Toxicology, Archives of Environmental Contamination and Toxicology, Journal of Environmental Quality, Environmental Pollution*; DOE proposals.
- Other: Ph.D. thesis committee member for Sylvia Talmage and Linda Meyers, University of Tennessee.

SIGAL, L. L.

- Chairman: 18th Annual Air Pollution Workshop, Chicago, Illinois, April 1986.
- Member: Environmental Sciences Division Awards Committee; Cochairperson, Environmental Analyses Section confabulations; United Way solicitor.
- Participant: Performance meeting with Weston consultants for the Tactical Air Command Environmental Compliance and Management Program (ECAMP) contract, December 1985; site visits for Vandenberg Air Force Base Biomonitoring Program, October–December 1985; meetings with Department of Energy Office of Audits and Compliance, January and March 1986; oversee Weston consultants for ECAMP assessment at MacDill Air Force Base, Florida, January 1986; site visit to Newport Army Ammunition Plant for the Draft Programmatic Environmental Impact Statement (DPEIS) for the Department of Army Chemical Stockpile Disposal Program, April 1986, and meetings with state agencies; scoping meetings for the DPEIS in Salt Lake City, Utah, and Denver, Colorado, April 1986; attendance at congressional hearing for the DPEIS in Richmond, Kentucky, July 1986; and public hearing for DPEIS, Richmond, Kentucky, August 1986; presentations at the public meetings on the DPEIS at Tooele, Utah, August 1986, and Umatilla, Oregon, August 1986.
- Ad hoc reviewer: *American Journal of Botany, The Bryologist, Water, Air, and Soil Pollution.*
- Other: Advisor to Suzanna Kirk, Robertsville High School Science Fair, April 1986.

SMITH, E. D.

- Participant: Department of Energy internal review of Nuclear Waste Policy Act program documents and Department of Energy environmental impact statements; Department of Energy Nuclear Waste Policy Act Environmental Assessment Workshop, Washington, D.C., October 1985; 6th National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D.C., November 1985; U.S. Geological Survey Southeast Region Ground-Water Modeling Workshop, Knoxville, Tennessee, November 1985; Nuclear Regulatory Commission Workshop on Validation of Mathematical Models for Waste Repository Performance Assessment, Bethesda, Maryland, January 1986; 3rd National Conference on

Hazardous Wastes and Hazardous Materials, Atlanta, Georgia, March 1986; Meeting on Prioritization Techniques/Ranking Methods, East Tennessee Chapter of the Society for Risk Analysis, Oak Ridge, Tennessee, July 1986; Save Our Cumberland Mountains review of Office of Surface Mining proposed actions and environmental impact statement.

Other: Environmental Effects Section Editor, *Nuclear Safety*; Secretary, Association for Women in Science, East Tennessee Chapter.

SOLOMON, A. M.

Chairman: Education Committee, Ecological Society of America, 1983-1987; Judge, Murray F. Buell Award Committee, Ecological Society of America.

Member: Argonne Peer Review Panel for Radwaste Site Selection.

Participant: Career Planning Course, ORNL, fall 1985; Workshop on Climate and Vegetation Interactions, Greenbelt, Maryland, January 1986; meeting on Modeling Plant Response to CO₂, Raleigh, North Carolina, March 1986; Workshop on Tree Rings and Forest Mensuration, Tucson, Arizona, April 1986; Biennial Meeting of American Quaternary Association, Urbana, Illinois, June 1986; International Conference on Health and Environmental Effects of Ozone Modification and Climate Change, Arlington, Virginia, June 1986; International Association for Vegetation Science Field Excursion, southern Norway, July 1986; International Ecological Congress and Ecological Society of America Meeting, Syracuse, New York, August 1986; International Symposium on Ecological Aspects of Tree-Ring Analysis, Tarrytown, New York, August 1986.

Ad hoc reviewer: Proposals: NSF; *Vegetatio*, *American Naturalist*, *Ecology/Ecological Monographs*, *American Journal of Botany*.

Other: Division Facilitator, Performance Improvement Process.

SOLOMON, J. A.

Chairman: Performance Improvement Process Team, Environmental Sciences Division Document Preparation Process.

Participant: Eighth Symposium on Biotechnology for Fuels and Chemicals, Gatlinburg, Tennessee, May 1986; annual meetings, Phycological Society of America and American Society for Limnology and Oceanography, Kingston, Rhode Island, June 1986; Subcontractors' Annual Review Meeting, Aquatic Species Program, Solar Energy Research Institute, Golden, Colorado, September 1986.

Ad hoc reviewer: *BioSystems*.

Other: Patterner, Martin Marietta Career Planning Workshop; Leader, ad hoc Environmental Sciences Division computer training class.

SOUTHWORTH, G. R.

Ad hoc reviewer: Proposals: U.S. Navy; *Environmental Science and Technology, Water, Air, and Soil Pollution, Environmental Toxicology and Chemistry.*

STEWART, A. J.

Advisor: Lynn Adams, Ph.D. candidate, University of Tennessee; Janet Burris, M.S. candidate, University of North Carolina at Chapel Hill; David Rosenberg, B.S. candidate, State University of New York at Binghamton.

Ad hoc reviewer: *Limnology and Oceanography, Journal of Freshwater Ecology*; proposals: NSF Ecology Program.

STOW, S. H.

Chairman: Geology Subcommittee of the ORNL Resource Management Committee; Town of Farragut Hydrology Committee.

Member: Geological Society of America (GSA) Membership Committee; Southeastern GSA Student Support Committee; Commission on Hazardous Waste of the International Association of Hydrogeologists; Environmental Sciences Division Education Committee; Auburn University Science and Math Advisory Committee; University of Tennessee Geosciences Advisory Committee; Oak Ridge Associated Universities Review Panel on Department of Energy Fellowships.

Participant: Annual Meeting, GSA, Orlando, Florida, October 1985; National Water Well Association Meeting, New Orleans, Louisiana, March 1986; Southeastern Section of GSA, Memphis, Tennessee, March 1986; American Association of Petroleum Geologists Annual Meeting, Atlanta, Georgia, June 1986; Underground Injection Practices Council Meeting, San Antonio, Texas, August 1986; HAZTECH International Meeting, Denver, Colorado, August 1986; International Association of Hydrogeologists Meeting, Czechoslovakia, September 1986.

Faculty: Adjunct Professor, University of Tennessee.

Advisor: Anne Scales, M.S. candidate, University of Tennessee.

Ad hoc reviewer: *Environmental Geology and Water Sciences* (Editorial Board); NSF proposals.

Other: Secretary-Treasurer of the Southeastern Section of the Geological Society of America; Oak Ridge Associated Universities Review Panel for the Department of Energy Fellowship Program on Nuclear Engineering and Health Physics; Radioactive Waste Management Editorial Board, *Environmental Geology and Water Sciences*; Oak Ridge Associated Universities Traveling Lecturer Program.

SUTER, G. W., II

- Member:** International Institute of Applied Systems Analysis Task Force on Risk and Policy Analysis Under Conditions of Uncertainty.
- Participant:** First Shackelton Point Workshop on Biotechnology Impact Assessment: Prospects for Biological Containment of Genetically Engineered Organisms, Cornell Biological Field Station, Bridgeport, New York, October 1985; 1985 Washington Conference on Environmental and Health Risk Assessment, Alexandria, Virginia, October 1985; meeting of ASTM Committee E-47 on Biological Effects and Environmental Fate, New Orleans, Louisiana, May 1986; Chairman, session on Environmental Modeling and Exposure Assessment, Tenth American Society for Testing and Materials (ASTM) Symposium on Aquatic Toxicology and Hazard Assessment, New Orleans, Louisiana, May 1986; Environmental Protection Agency Ecological Risk Assessment Research Program All Investigators Meeting, Athens, Georgia, August 1986.
- Advisor:** Linda Mountain, B.S. candidate, Fort Valley State College, Fort Valley, Georgia.
- Ad hoc reviewer:** EPA (proposals, monitoring plans for genetically engineered microorganisms, and guidelines for a soil microbial community toxicity test); Hudson River Foundation proposals; ASTM Tenth Symposium on Aquatic Toxicology and Hazard Assessment; *Environmental Toxicology and Chemistry*, *BioScience*.

TAMURA, T.

- Chairman:** Environmental Sciences Division Scientific Achievement Award Committee.
- Member:** Oak Ridge Reservation Resource Management Committee, Martin Marietta Energy Systems; Environmental Quality Research Award Committee, American Society of Agronomy; Nevada Applied Ecology Group Investigators Committee, Nevada Operations Office.
- Participant:** Groundwater Short Course, San Francisco, California, July 1986; Cleanup Planning and Evaluation, Castle Air Force Base, Merced, California, July 1986; Cleanup Task Force, Australian/British Information Exchange, Las Vegas, Nevada, May 1986; Technology Transfer Meeting, Nevada Applied Ecology Group/Uranium Mill Tailings Remedial Action Program work session, Las Vegas, Nevada, July 1986.
- Consultant:** Grouting Demonstration Program, EG&G-Idaho, Idaho Falls, Idaho; Environmental Assessment Department, Electric Power Research Institute, Palo Alto, California; Remedial Action on Contaminated Lands, Rocky Flats Plant, Colorado.

Ad hoc reviewer: *Nuclear Technology.*

Other: Review Editor, Biogeochemical Cycling in Walker Branch Watershed.

TAYLOR, G. E.

Member: Natural Sources Task Group, Interagency Task Force on Acid Precipitation; Clean Air Scientific Advisory Committee, Scientific Advisory Board, of the Environmental Protection Agency.

Participant: U.S. Department of Energy Workshop on Research Priorities in Terrestrial Plant Ecology, Fort Worden, Washington, October 1985; U.S. Forest Service Workshop on Research Planning for Studying Atmospheric Deposition on Deciduous Forests of Eastern United States, Downingtown, Pennsylvania, January 1986; Session Chairman, Environmental Protection Agency Workshop on Forest Tree Exposure Methodologies, Corvallis, Oregon, January 1986; National Acid Precipitation Assessment Program Workshop on Dry Deposition, Harper's Ferry, West Virginia, March 1986; American Society of Plant Physiologists, Baton Rouge, Louisiana, June 1986; Second European Open-Top Chamber Workshop, Freiburg, Federal Republic of Germany, September 1986; International Union of Forest Research Organisations Symposium on Whole-Plant Physiology, Knoxville, Tennessee, October 1986.

Ad hoc reviewer: *Water, Air, and Soil Pollution, Trends in Ecology and Evolution, Environmental and Experimental Botany*; proposals: DOE and NOAA.

TOLBERT, V. R.

Chairman: Sigma Xi Nominating Committee.

Member: Rural Abandoned Mine Program (RAMP) Reclamation Committee for Tennessee; document reviewer for U.S. Synfuels Corp./U.S. Treasury.

Participant: Preparation of Environmental Assessment for Renewal of Special Nuclear Material License for Nuclear Fuel Services, Erwin, Tennessee; Draft Environmental Impact Statement related to the operation of South Texas Project, Units 1 and 2; Preliminary Draft Environmental Assessment for the Relocation of the Air Force Engineering Services Center Contingency Training Facility, Eglin Air Force Base, Florida; Preliminary Assessment of the Health and Environmental Impacts of Incinerating M55 Rockets Stored at Pine Bluff Arsenal, Lexington-Blue Grass Depot Activity, and/or Anniston Army Depot at Pine Bluff Arsenal; Preliminary Assessment of the Health and Environmental Impacts of Transporting M55 Rockets from Lexington-Blue Grass Depot Activity, Anniston Army Depot, and Umatilla Depot Activity to Alternative Disposal Facilities; Preliminary Assessment of the Health and Environmental Impacts of Continuing to Store M55 Rockets at Lexington-Blue Grass Depot Activity, Anniston Army Depot, Umatilla Depot Activity,

Pine Bluff Arsenal, and Tooele Army Depot; Chemical Stockpile Disposal Program Draft Programmatic Environmental Impact Statement; long-term problems of land contaminated by nonradioactive hazardous chemicals: sources, impacts, and countermeasures; standard format and contents of environmental reports for the License Renewal of Fuel Fabrication and UF₆ Conversion Facilities; standard review plan for Environmental Assessment of Nuclear Fuel Cycle Facilities; unpublished final report for basewide environmental monitoring at Vandenberg Air Force Base, California.

Ad hoc reviewer: Rock Creek Watershed Petition Evaluation Document/Environmental Impact Statement; Office of Surface Mining Draft Statement.

Other: Preparer, membership directory for American Society for Surface Mining and Reclamation.

TRABALKA, J. R.

Member: Panel member, Working Group II (Cycling of Carbon and Other Radiatively Active Constituents) in the International Conference: An Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts, Villach, Austria, October 1985; ORNL Professional Education Resource Committee for Life Sciences.

Other: Editor, Proceedings, Sixth ORNL Life Sciences Symposium, The Changing Carbon Cycle: A Global Analysis, Knoxville, Tennessee, October–November 1983, completed in March 1986; Coordinator/Editor: State-of-the-Art Report on Global Carbon Cycle Research: Atmospheric Carbon Dioxide and the Global Carbon Cycle, Department of Energy, completed in January 1986.

TRIPATHI, V. S.

Participant: American Geophysical Union Meeting, San Francisco, California, December 1986; Nuclear Regulatory Commission (NRC) Geochemistry Workshop, Bethesda, Maryland, January 1986; NRC Geochemistry Workshop, Silver Spring, Maryland, May 1986; Gordon Conference on Environmental Sciences, New Hampton, New Hampshire, June 1986; American Chemical Society National Meeting, Anaheim, California, September 1986; Cray Computing Course, University of Tennessee, Knoxville, September 1986; Hypercube Conference, Knoxville, Tennessee, September–October 1986.

Ad hoc reviewer: *Journal of Colloid Interfacial Science*; DOE and NSF proposals.

TURNER, R. R.

Member: Oak Ridge Interim Action Study Group; Y-12 Subcontractor Sampling and Analytical Chemistry Audit Team.

Participant: International Conference on Heavy Metals in the Environment, Athens, Greece, September 1985; 2nd Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985; annual review, Electric Power Research Institute, Aluminum in Streams Study, Washington, D.C., April 1986.

Advisor: Mari Ann Zeiler, B.A. candidate, Carleton College.

Ad hoc reviewer: Proposals: NSF, Martin Marietta Energy Systems.

TURNER, R. S.

Participant: U.S. Department of Energy REFLEX Planning Meeting, University of Delaware, Lewes, Delaware, October 1985; Soil Science Society of America Annual Meeting, Chicago, Illinois, December 1985; National Council on Air and Stream Improvement (NCASI) Operating Committee Task Group on Air Quality and Forest Health, Oak Ridge, Tennessee, December 1985; Environmental Protection Agency Watershed Manipulation Project Planning Meeting, Oak Ridge, Tennessee, December 1985; Direct/Delayed Response Project (DDRP), Northeast U.S. Field Sampling Wrap-Up Meeting, Las Vegas, Nevada, January 1986; Aquatic Effects Assessment Briefing of L. Kulp, J. Malanchuk, and C. Riorden, Washington, D.C., January 1986; DDRP Southern Blue Ridge Province Soil Correlation and Sampling Unit Workshop, Corvallis, Oregon, March 1986; DDRP Soil Sampling Training Workshop, Knoxville, Tennessee, March 1986; Scientific Committee on Problems of the Environment Workshop on Acidification in the Tropics, Caracas, Venezuela, April 1986; DDRP Data Management-Verification-Validation Workshop, Corvallis, Oregon, May 1986; Electric Power Research Institute-Environmental Protection Agency-National Council on Air and Stream Improvement (EPRI-EPA-NCASI) Soil Weathering Workshop, Knoxville, Tennessee, May 1986; DDRP Level III Analysis Workshop, Corvallis, Oregon, June-July 1986; DDRP Data Management-Verification-Validation workshops, Oak Ridge, Tennessee, July-August 1986; DDRP Watershed Data Aggregation Workshop, Oak Ridge, Tennessee, September 1986.

Advisor: Alan Stam, Ph.D. candidate, University of Tennessee.

Ad hoc reviewer: Proposals: EPA, TVA, NAPAP; *Forest Science*, *Journal of Environmental Quality*, *Science*, *Soil Science Society of America Journal*.

TYNDALL, R. L.

- Participant:** Oak Ridge Operations Industrial Hygiene Advisory Committee meetings.
- Faculty:** Research Associate Professor, Zoology Department, University of Tennessee.
- Advisor:** Advisor to numerous Department of Energy facilities, the U.S. Navy, and various industries on the control of *Legionella* and *Acanthamoebae*. Also advisor for Elizabeth Domingue, M.S. candidate, Environmental Health Department, East Tennessee State University.
- Ad hoc reviewer:** Proposals: Environmental Protection Agency, Hudson River Foundation, and U.S. Army.
- Consultant:** Northern States Power, Minneapolis, Minnesota; Illinois Power Company, Decatur, Illinois; Charles C. Main, Inc., Boston, Massachusetts.

VAN HOOK, R. I.

- Chairman:** Planning Committee for the Fourth Southern Biomass Research Conference, Athens, Georgia, October 1986.
- Member:** Southern Regional Biomass Program Advisory Committee; Southern Biomass Research Conference Planning Committee.
- Participant:** Program Management Team, Biomass Production, Biofuels and Municipal Waste Technology Division, Department of Energy.
- Faculty:** Adjunct faculty member, Graduate Program in Ecology, University of Tennessee.
- Other:** Associate editor, *Biomass*.

VAN WINKLE, W.

- Chairman:** Environmental Sciences Division Awards Coordinator.
- Member:** Aquatic Effects Task Group of the National Acid Precipitation Assessment Program; Environmental Sciences Division Scientific Achievement Award Committee.
- Participant:** Second Annual Acid Rain Conference for the Southern Appalachians, Gatlinburg, Tennessee, October 1985; Electric Power Research Institute Aluminum Stream Study, annual review, Washington, D.C., April 1986; peer review of Environmental Protection Agency's Watershed Manipulation Project, Atlanta, Georgia, June 1986; Lake Acidification and Fisheries Workshop, Oak Ridge, Tennessee, May 1986.
- Faculty:** Faculty Associate, University of Tennessee; Adjunct Faculty, University of Wyoming.

Ad hoc reviewer: *Canadian Journal of Fisheries and Aquatic Sciences, Estuaries, Transactions of the American Fisheries Society*; International Symposium on Common Strategies of Anadromous and Catadromous Fishes; National Acid Precipitation Assessment Program; proposals: NSF, EPA Watershed Manipulation Project.

VON DAMM, K. L.

Participant: American Geophysical Union Meeting, San Francisco, California, December 1985; SRP/NRC Waste Package Meeting, Columbus, Ohio, January 1986; American Geophysical Union Meeting, Baltimore, Maryland, May 1986; American Chemical Society Meeting, Anaheim, California, September 1986; LLNL Workshop on Geochemical Modeling, South Lake Tahoe, California, September 1986.

Ad hoc reviewer: Proposals: National Science Foundation; *Environmental Geology and Water Sciences, Journal of Geophysical Research*.

VOORHEES, L. D.

Chairman: Natural Subgroup for Department of Energy-Oak Ridge Reservation Resource Management Organization.

Participant: Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Law and Regulations Course, Washington, D.C., October 1985; Resource Conservation and Recovery Act (RCRA) Regulations Course, Washington, D.C., October 1985; ORNL Management Resource Development Course: Interpreting Monthly Cost Reports, October 1985; Sixth National Conference and Exhibition on Management of Uncontrolled Hazardous Waste Sites, Washington, D.C., November 1985; SAS Course on Programming for New Computer Users, Cary, North Carolina, December 1985; ORNL Management Resource Development Course: Management of Meetings, April 1986; Environmental Protection Agency STORET Training Course, Oak Ridge, Tennessee, August 1986.

Ad hoc reviewer: *Nuclear Safety*.

WALTON, B. T.

Participant: Society of Environmental Toxicology and Chemistry (SETAC) Annual Meeting, St. Louis Missouri, November 1985; SETAC, Executive Committee Meeting (Chair), Washington, D.C., January 1986; SETAC Board of Directors' meetings (Chair), Washington, D.C., March, June, September 1986; SETAC Ozark-Prairie Regional Chapter Annual Meeting, Columbia, Missouri, May 1986; Robert S. Kerr Environmental Research Laboratory Seminar, Oklahoma City, Oklahoma, April 1986;

National Academy of Sciences/National Research Council Committee on Environmental Risk Assessment of Pyrethroids, Washington, D.C., January and March 1986, and Williamsburg, Virginia, July 1986; Southeastern Symposium on In-situ Treatment and Immobilization of Hazardous and Radioactive Wastes, Knoxville, Tennessee, June 1986; Contaminant Mobility Working Group of the U.S. Army Corps of Engineers, Waterways Experiment Station, the Netherlands Organization for Applied Scientific Research; and the Delta Institute of Hydrobiological Research, September 1986, Rotterdam, Netherlands.

Faculty: Faculty Associate in Ecology and member of the Toxicology Steering Committee, University of Tennessee.

Advisor: S. S. Talmage, Ph.D. candidate, University of Tennessee; L. J. Meyers, Ph.D. candidate, University of Tennessee; thesis committee member for A. Johnson, Ph.D. candidate, University of Tennessee; M. Black, Ph.D. candidate, University of Tennessee; W. Burton, Ph.D. candidate, University of Tennessee.

Ad hoc reviewer: *Environmental Toxicology and Chemistry*; proposals: EPA.

WATERHOUSE, J. C.

Participant: Symposium on Nonequilibrium Community Ecology, Ecological Society of America Annual Meeting, Minneapolis, Minnesota, June 1985.

WATTS, J. A.

Member: Awards Committee, American Women in Science, East Tennessee Chapter, 1986.

Participant: Workshop on Directions for Internationally Compatible Environmental Data, McGill University, Montreal, Quebec, Canada, May 1986; Forest Effects Workshop, Environmental Protection Agency, Corvallis, Oregon, October 1985; International Institute for Applied Systems Analysis Modeling Data Meeting, Tetra Tech, Inc., Lafayette, California, December 1985; NE Soil Survey Wrap-Up Meeting, Environmental Protection Agency, Las Vegas, Nevada, January 1986; SE Soil Survey Mapping and Site Selection Workshop, Environmental Protection Agency, Corvallis, Oregon, March 1986; SE Field Training Protocol Workshop, Environmental Protection Agency, University of Tennessee, Knoxville, Tennessee, March 1986; Directions for Internationally Compatible Environmental Data Workshop, CODATA, McGill University, Montreal, Quebec, Canada, May 1986.

WEBB, J. W.

Member: Environmental Sciences Division Seminar Committee; ORNL Hydrofracture Facility Remedial Action Quality Assurance Team.

Participant: Preparation of Final Environmental Impact Statement, South Texas Nuclear Power Plant, Operating License; Draft Environmental Impact Statement, Owens River Basin, Seven Hydroelectric Projects, California; Environmental Analysis, Pleasant Bayou Geopressure Well Utilization Project; Risk-Benefit Analysis, Implementation Risk to Ecological Resources of Remedial Action Options at Four Sites on the Oak Ridge Reservation.

Ad hoc reviewer: NSF proposals; Entomology Society journals, *Journal of Environmental Quality*, *Biotropica*, *The Environmental Professional*.

WRIGHT, L. L.

Chairman: Program Chairman for Association of Women in Science, East Tennessee Chapter; Energy Committee, Poplar Council of the United States; Vice President, Tennessee Citizens for Wilderness Planning.

Participant: International Union of Forestry Research Organisations Symposium on Tree Physiology, Knoxville, Tennessee, October 1985; Northeast Regional Biomass Program Steering Committee Meeting, September 1986.

Ad hoc reviewer: Small Business Innovation Research proposal for the Department of Energy.

YEH, G. T.

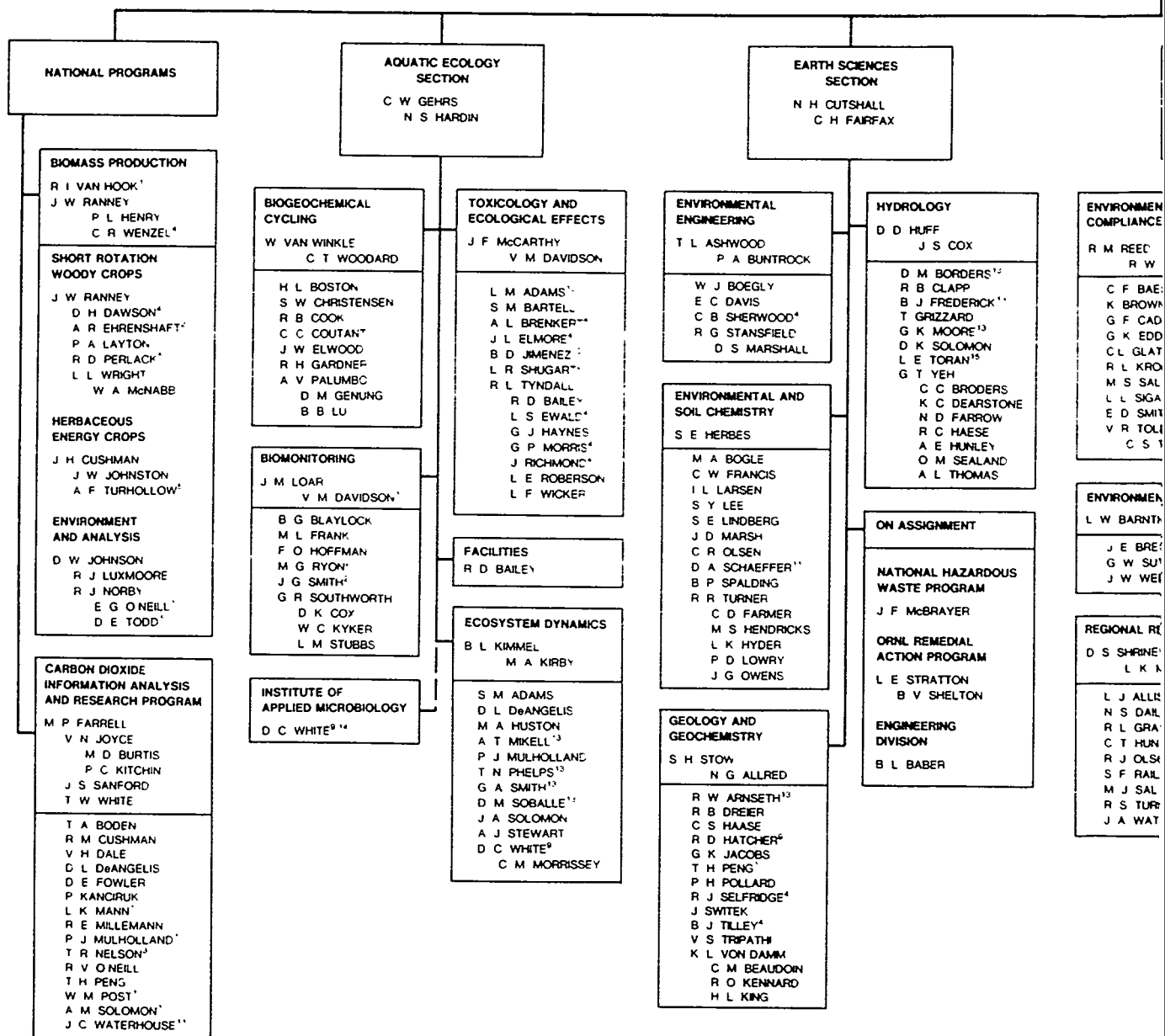
Member: American Society of Civil Engineers Subcommittee N-173.

Ad hoc reviewer: *Water Resources*; proposals: NSF, DOE, USGS, American Society of Civil Engineers Committee on Hydrologic Transport and Dispersion.

ENVIRONMENTAL S

MARCH

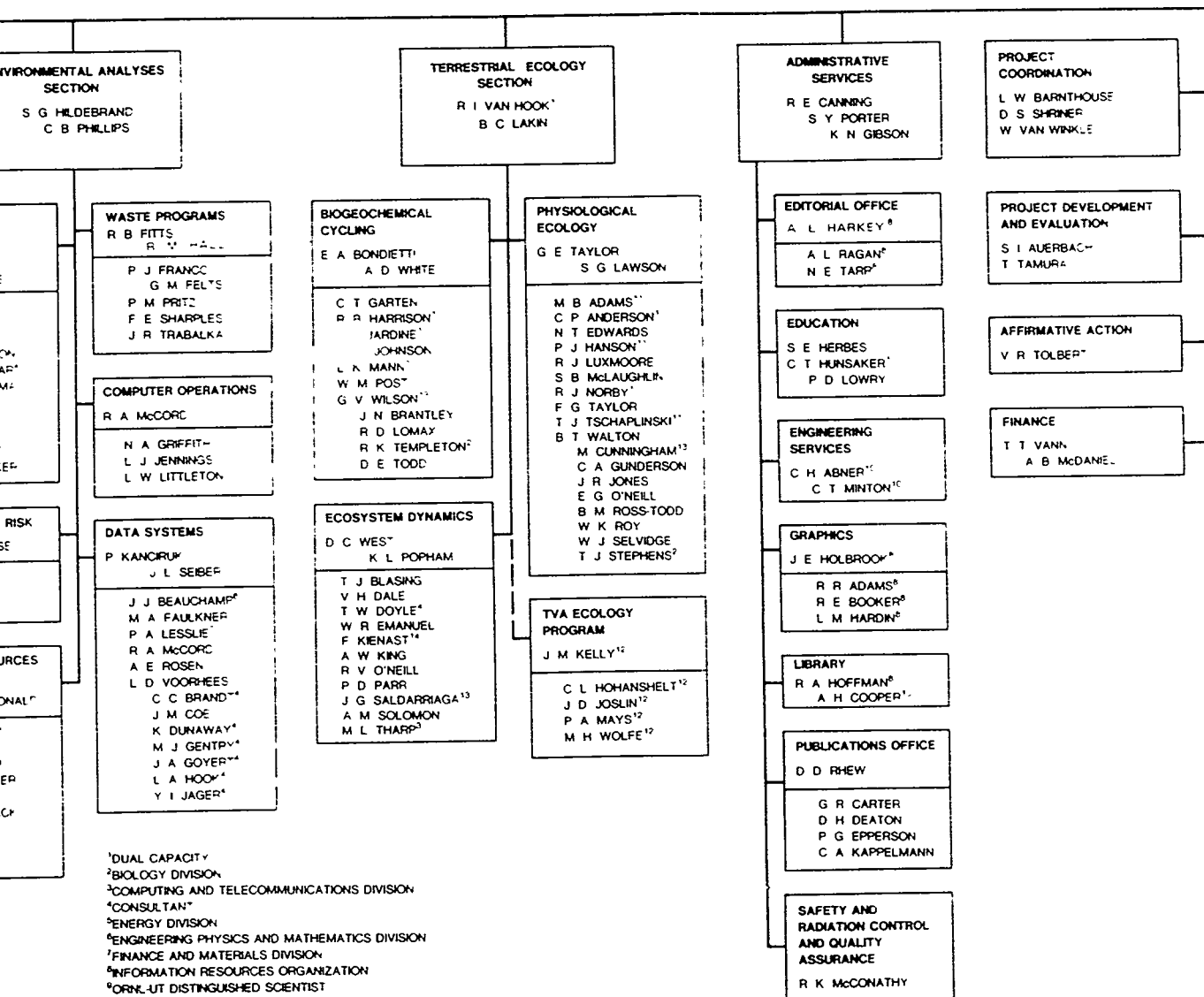
DIRECT
D E REK
D M V
R O V



RENCES DIVISION

7

CH
INGTON



¹DUAL CAPACITY

²BIOLOGY DIVISION

³COMPUTING AND TELECOMMUNICATIONS DIVISION

⁴CONSULTANT

⁵ENERGY DIVISION

⁶ENGINEERING PHYSICS AND MATHEMATICS DIVISION

⁷FINANCE AND MATERIALS DIVISION

⁸INFORMATION RESOURCES ORGANIZATION

⁹ORN-LUT DISTINGUISHED SCIENTIST

¹⁰PLANT AND EQUIPMENT DIVISION

¹¹POSTDOCTORAL FELLOW

¹²TENNESSEE VALLEY AUTHORITY

¹³UNIVERSITY OF TENNESSEE

¹⁴VISITING SCIENTIST

¹⁵WIGNER FELLOW

INTERNAL DISTRIBUTION

1. L. M. Adams	50. M. P. Farrell	99. A. P. Malinauskas	272. W. D. Shults II
2. M. B. Adams	51. M. A. Faulkner	100. L. K. Mann	273. L. L. Sigal
3. S. M. Adams	52. R. B. Pitts	101. J. D. Marsh	274. E. D. Smith
4. L. J. Allison	53. D. E. Fowler	102. J. P. McCarthy	275. D. M. Soballe
5. R. W. Arnseth	54. M. L. Frank	103. L. L. McCauley	276. A. M. Solomon
6. T. L. Ashwood	55. W. Fulkerson	104. R. K. McConathy	277. D. K. Solomon
7. J. T. Atherton	56. R. H. Gardner	105. L. K. McDonald	278. J. A. Solomon
8. S. I. Auerbach	57. C. T. Garten	106. W. A. McNabb	279. B. P. Spalding
9. C. F. Baes III	58. C. W. Gehrs	107. R. E. Millemann	280. C. Stair
10. L. W. Barnthouse	59. K. N. Gibson	108. M. E. Mitchell	281. A. J. Stewart
11. V. B. Baylor	60. C. Glatthaar	109. G. K. Moore	282. S. H. Stow
12. J. J. Beauchamp	61. R. Graham	110. C. Moriones	283. L. E. Stratton
13. C. M. Beaudoin	62. R. A. Griesemer	111. P. J. Mulholland	284. G. W. Suter
14. B. A. Berven	63. W. A. Griffith	112. T. E. Myrick	285. J. Switek
15. T. J. Blasing	64. T. Grizzard	113. R. J. Norby	286. T. Tamura
16. B. G. Blaylock	65. C. A. Gunderson	114. E. G. O'Neill	287. N. E. Tarr
17. T. A. Boden	66. C. S. Haase	115. R. V. O'Neill	288. F. G. Taylor, Jr.
18. W. J. Boegly, Jr.	67. P. J. Hanson	116. C. R. Olsen	289. G. E. Taylor
19. E. A. Bondietti	68. P. L. Henry	117. R. J. Olson	290. A. L. Thomas
20. D. M. Borders	69. S. E. Herbes	118. J. G. Owens	291. V. R. Tolbert
21. C. C. Brandt	70. S. G. Hildebrand	119. A. V. Palumbo	292. J. R. Trabalka
22. J. E. Breck	71. F. O. Hoffman	120. P. D. Parr	293. J. L. Trimble
23. C. Broders	72. F. J. Homan	121. D. C. Parzyck	294. C. S. Tucker
24. M. D. Burtis	73. D. D. Huff	122. T.-H. Peng	295. R. R. Turner
25. T. R. Butz	74. C. T. Hunsaker	123. C. B. Phillips	296. R. S. Turner
26. G. F. Cada	75. M. A. Huston	124. S. Y. Porter	297. R. L. Tyndall
27. J. B. Cannon	76. G. K. Jacobs	125. W. M. Post	298. R. I. Van Hook
28. R. Carlsmith	77. D. W. Jared	126. H. Postma	299. W. Van Winkle
29. R. O. Chester	78. B. Jimenez	127. M. L. Poutsma	300. K. L. Von Damm
30. S. W. Christensen	79. J. W. Johnston	128. A. Ragan	301. L. D. Voorhees
31. R. B. Cook	80. J. R. Jones	129. J. W. Ranney	302. R. O. Wadlington
32. C. C. Coutant	81. V. M. Joyce	130. R. M. Reed	303. P. J. Walsh
33. J. S. Cox	82. C. A. Kappelmann	131-255. D. E. Reichle	304. B. T. Walton
34. A. G. Croff	83. S. V. Kaye	256. D. D. Rhew	305. J. A. Watts
35. J. H. Cushman	84. J. M. Kelly	257. C. R. Richmond	306. C. R. Wenzel
36. R. M. Cushman	85. B. Kennard	258. L. E. Roberson	307. A. D. White
37. N. H. Cutshall	86. R. H. Ketelle	259. P. S. Rohwer	308. T. White
38. W. S. Dailey	87. B. L. Kimmel	260. M. W. Rosenthal	309. D. M. Wiffen
39. V. H. Dale	88. H. L. King	261. T. H. Row	310. R. Wiltshire
40. V. M. Davidson	89. J. T. Kitchings III	262. M. Ryon	311. L. L. Wright
41. E. C. Davis	90. C. H. Krause	263. M. J. Sale	312. R. G. Wymer
42. T. L. Donaldson	91. R. L. Kroodasma	264. M. S. Salk	313. G. T. Yeh
43. R. B. Dreier	92. B. C. Lakin	265. J. S. Sanford	314. Central Research Library
44. R. E. Durfee	93. I. L. Larsen	266. J. L. Seiber	315. ESD Library
45. N. T. Edwards	94. S. Y. Lee	267. R. J. Selfridge	316-317. Laboratory Records Dept.
46. J. W. Elwood	95. S. E. Lindberg	268. F. E. Sharples	318. Laboratory Records, ORNL-RC
47. P. C. Epperson	96. C. D. Little	269. B. V. Shelton	319. ORNL Patent Section
48. L. D. Eymann	97. J. M. Loar	270. R. B. Shelton	320. ORNL Y-12 Technical Library
49. C. H. Fairfax	98. R. J. Luxmoore	271. D. S. Shriner	

EXTERNAL DISTRIBUTION

321. V. Dean Adams, Tennessee Technological University, Cookeville, TN 38501	
322. J. Frances Allen, Science Advisory Board, Environmental Protection Agency, Washington, DC 20460	
323. C. C. Amundsen, University of Tennessee, Ecology, 408 Tenth Street, Knoxville, TN 37916	
324. F. Andersson, Swedish Coniferous Forest Project, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, P.O. Box S-750 07, Uppsala, Sweden	
325. J. W. Arthur, Director, Monticello Experimental Research Station, Environmental Protection Agency, Monticello, NM 55362	
326. D. C. Aumann, Institut Fur Physikalische Chemie, der Universitat Bonn, Abt Nuklearchemie, Wegelerstrasse 12, 5300 Bonn 1, Federal Republic of Germany	
327. Nilda Ayala, U.S. Environmental Protection Agency, Stop 8-1/2, Fernandez Juncos Avenue, Puerta de Tierra, Box 792, San Juan, Puerto Rico 00902	
328. R. B. Bacastow, Scripps Institution of Oceanography, University of California, 2314 Rittler Hall, A-020, La Jolla, CA 92093	
329. D. D. Bacon, Forest Hydrologist, U.S. Department of Agriculture, Forest Service, 50 Seventh Street, NE, Atlanta, GA 30309	
330. John Barker, Director, Office of Environmental Audit, EH-24, U.S. Department of Energy, 1000 Independence Ave., NW, Washington, DC 20585	
331. Burton V. Barnes, Department of Forestry, School of Natural Resources, University of Michigan, Ann Arbor, MI 48104	
332. Ann Bartuska, Program Coordinator, USDA Forest Service, Southern Commercial Forest Research Program, 1509 Varsity Avenue, Raleigh, NC 27606	
333. B. C. Bennett, Monitoring and Assessment Research Center, 459A Fulham Road, London SW10 0QX, England	
334. D. A. Bennett, Environmental Protection Agency, RD 680, 401 M Street, SW, Washington, DC 20460	
335. R. A. Benson, Director, Office of Renewable Technology, Department of Energy, Washington, DC 20585	
336. H. L. Bergman, Department of Zoology and Physiology, University of Wyoming, P.O. Box 3067, University Station, Laramie, WY 82071	
337. R. P. Berube, Office of Environmental Guidance and Compliance, EH-23, DOE, Washington, DC 20585	
338. B. Bolin, Department of Meteorology, University of Stockholm, S-106 91 Stockholm, Sweden	
339. Juan A. Bonnet, Jr., Center for Energy and Environmental Research, University of Puerto Rico, Caparra Heights Station, San Juan, PR 00935	
340. C. M. Borgstrom, Director, Office of NEPA Project Assistance, EH 25, U.S. Department of Energy, 1000 Independence Ave., N.W., Washington, DC 20585	
341. Daniel B. Botkin, Environmental Studies Program, University of California, Santa Barbara, Santa Barbara, CA 93106	
342. Philippe Bourdeau, Director, Environment, Raw Materials & Materials Technology, Commission of the European Communities, Rue de la Loi 200, Brussels XII/F, Belgium	
343. R. W. Brocken, Living Lakes, 1090 Vermont Ave., NW, Suite 510, Washington, DC 20005	
344. W. S. Broecker, Lamont Doherty Geological Observatory, Columbia University, Palisades, NY 10964	
345. J. L. Brooks, Director, Biotic Systems and Resources Division, National Science Foundation, Washington, DC 20550	
346. J. D. Buffington, Director, Office of Biological Services, U.S. Fish and Wildlife Services, 1730 K Street, NW, Washington DC 20240	
347. Dewey Bunting, Graduate Program in Ecology, University of Tennessee, Knoxville, TN 37916	
348. Harry T. Burn, Technical Librarian, ORAU/MKRT, Oak Ridge, TN 37831	

349. Elton J. Cairns, Associate Director, Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, CA 94720
350. J. Cairns, Center for Environmental Studies, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061
351. J. Thomas Callahan, Associate Director, Ecosystem Studies Program, Room 336, 1800 G Street, NW, National Science Foundation, Washington, DC 20550
352. Melvin G. R. Cannell, Institute of Terrestrial Ecology, Edinburgh Research Station, Bush Estate, Penicuik, Midlothian, EH26 0QB, U. K.
353. P. M. Cate, International Atomic Energy Agency, P.O. Box 590, Karnthner Ring 11, A-1011, Vienna, Austria
354. J. P. Clugston, Director, National Fish Research Laboratory, 7920 N.W. 71st Street, Gainesville, FL 32606
355. Dale W. Cole, College of Forest Resources, University of Washington, Seattle, WA 98105
356. G. R. Conway, Director, Imperial College Center for Environmental Technology, Imperial College of Science and Technology, 48 Prince's Gardens, London SW7, England
357. Raymond Costello, Biofuels and Municipal Waste Technology, CE 341, Department of Energy, 600 E Street, NW, Washington, DC 20585
358. J. M. Crockett, Westvaco Timberlands, P.O. Box 1950, Summerville, SC 29484
359. F. A. Cross, Director, Southeast Fisheries Center, Beaufort, NC 28516
360. C. E. Cushing, Ecosystems Department, Battelle-Northwest Laboratories, Richland, WA 99352
361. John Cushman, Director, Water Resources Research Center, Lilly Hall of Life Sciences, Purdue University, West Lafayette, IN 47907
362. R. C. Dahlman, Office of Basic Energy Sciences, Carbon Dioxide Research Division, Code ER-12, Room J-311, Department of Energy, Washington, DC 20545
363. David H. Dawson, 1835 N. Stevens St., P.O. Box 1321, Rhinelander, WI 54501
364. E. T. Degens, SCOPE/UNEP International Carbon Center, Universität Hamburg, Bundesstrasse 55, D-2000 Hamburg 13, Federal Republic of Germany
365. Frank D'Itri, Institute of Water Research, Michigan State University, East Lansing, MI 48824
366. C. Delisi, Associate Director for Health and Environmental Research, Office of Energy Research, ER-70, Department of Energy, Washington, DC 20545
367. D. J. Donoghue, Division of Waste and Scrap Management, Department of Energy, Washington, DC 20545
368. Janet V. Dorigan, Office of Health and Environmental Research, Department of Energy, Washington, DC 20545
369. J. Eaton, Environmental Research Laboratory-Duluth, 6201 Congdon Blvd., Duluth, MN 55804
370. James A. Edmonds, Battelle Memorial Institute, Pacific Northwest Laboratories, 2030 M Street NE, Washington, DC 20036
371. H. C. Eichhorn, Chief, Biology Branch, Water Quality Engineering Division, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD 21010
372. Carl D. Eklund, Tennessee Valley Authority, Division of Water Control Planning, 345 Edney Building, Knoxville, TN 37902
373. Charles E. Elderkin, Manager, Atmospheric Sciences Department, Battelle-Pacific Northwest Laboratory, P.O. Box 999, Richland, WA 99352
374. W. Gary Ernst, Department of Earth and Space Sciences, University of California at Los Angeles, Los Angeles, CA 90024
375. J. Falco, U.S.E.P.A. Office of Research and Development, RD-682, 401 M St., SW, Washington, DC 20460
376. L. Farges, Project Officer of the Coordinated Research Programme, Division of Nuclear Safety and Environmental Protection, International Atomic Energy Agency, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria
377. G. D. Farquhar, Department of Environmental Biology, The Australian National University, P.O. Box 475, Canberra City, A.C.T. 2601, Australia
378. William E. Felling, Executive Director, Oak Ridge Associated Universities, Oak Ridge, TN 37831
379. John E. Ferrell, Program Manager, Biofuels and Municipal Waste Technology Division, CE-341, U.S. Department of Energy, Washington, DC 20545
380. John V. Flynn, Department of Energy, Division Geothermal & Hydropower Technology, CE-324, 1000 Independence Ave., SW, RM 5F-035B, Washington, DC 20585
381. G. J. Foley, Office of Environmental Process and Effects Research, U.S. Environmental Protection Agency, 401 M Street, SW, RD-682, Washington, DC 20460
382. S. W. Fowler, International Laboratory of Marine Radioactivity Musel Oceanographique, Principality of Monaco
383. David Friedman, Hazardous Waste Management Division (WH-565), Office of Solid Waste, Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460
384. Robert M. Friedman, Office of Technology Assessment, U.S. Congress, 600 Pennsylvania Avenue SE, 4th Floor, Washington, DC 20003
385. I. Y-S. Fung, NASA Goddard Space Flight Center, 2880 Broadway, New York, NY 10025
386. Eliezer Gilat, Principal Marine Biologist, Associate Professor, Ministry of Agriculture, Fisheries Technology Unit, P.O. Box 299, Haifa 31000, Israel
387. Vernon C. Gilbert, National History Division, National Park Service, Washington, DC 20240
388. Jim Gilford, Branch Chief, Office of Toxic Substances, Environmental Review Division, Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460
389. Bill Glase, Director, Environmental Sciences and Engineering Program, University of California at Los Angeles, Los Angeles, CA 90032
390. C. R. Goldman, Professor of Limnology, Division of Environmental Studies, University of California, Davis, CA 94616
391. Elizabeth C. Goodsen, Department of Energy, Savannah River Operations Office, P.O. Box A, Aiken, SC 29801
392. Lennart Granat, Stockholms Universitet, Meteorologiska Institutionen, Arrheniuslaboratoriet, 10691 Stockholm, Sweden
393. Phillip E. Greeson, Assistant Regional Hydrologist, U. S. Geological Survey, R. B. Russell Federal Building, 75 Spring Street, SW, Suite 772, Atlanta, GA 30303
394. Thomas J. Gross, Carbon Dioxide Research Division, Office of Basic Energy Sciences, Code ER-12, U.S. Department of Energy, Washington, DC 20545
395. D. H. Hamilton, Division of Ecological Research, Office of Health and Environmental Research, Department of Energy, Washington, DC 20545
396. W. F. Harris, Deputy Division Director, Division of Biotic Systems and Resources, National Science Foundation, 1800 G Street, NW, Room 1140, Washington, DC 20550
397. John Harrison, Chief, Environmental Laboratory, Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180
398. Fred Hatch, Lawrence Livermore Laboratory, P.O. Box 808, Livermore, CA 94550
399. Paul Hayes, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555
400. A. D. Hecht, Director, National Climate Program Office, NOAA, 6010 Executive Blvd., Rockville, MD 20852
401. Robert Herbst, Department of Interior, 18th and C Street, NW, Washington, DC 20240
402. Gerald D. Hertel, U.S. Forest Service, Northeast Forest Experiment Station, 370 Reed Road, Broomall, PA 19008
403. H. E. Hodgdon, The Wildlife Society, 5410 Grosvenor Lane, Bethesda, MD 20814
404. Kenneth Hoeltje, Forest Hydrologist, U.S. Department of Agriculture, Forest Experiment Station, Box 2750, Asheville, NC 28807
405. J. S. Hoffman, Energy Policy Division, 432 W. PM 221, EPA, 401 M Street NW, Washington, DC 20460
406. David R. Hopkins, Environmental Protection Agency, 345 Courtland Street, NE, Atlanta, GA 30365
407. R. A. Houghton, The Ecosystems Center, Marine Biological Laboratory, 167 Water St., Woods Hole, MA 02543
408. J. W. Huckabee, Manager, Ecological Studies Program, Electric Power Research Institute, 3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303
409. Boyd A. Hutchinson, Atmospheric Turbulence and Diffusion Laboratory, 465 S. Illinois Ave., Oak Ridge, TN 37831
410. O. Ilari, Divisione Protezione Sanitaria e Controlli, CNEN, Biolo Regina Margherita 125, 00198 Roma, Italy
411. Institute of Limnology, Box 557, 751 22 Uppsala 1, Sweden
412. Paul C. Jarvis, Department of Forestry and Natural Resources, University of Edinburgh, Edinburgh, Scotland EH9 3JU, United Kingdom
413. Norb Jaworski, Environmental Research Laboratory Duluth, 6201 Congdon Blvd., Duluth, MN 55804
414. V. Jellen, Environmental Protection Agency, Environmental Research Laboratory, Cincinnati, OH 45268
415. R. M. Jenkins, National Reservoir Research Program, U.S. Fish and Wildlife Service, Fayetteville, AR 72701
416. Beth Jinkerson, Oak Ridge Associated Universities, University Programs Division, 130 Badger Avenue, Oak Ridge, TN 37830
417. Karl J. Johansen, Department of Radioecology, Swedish University of Agricultural Sciences, Uppsala, Sweden
418. Herb Jones, Tennessee Valley Authority, Air Quality Branch, Muscle Shoals, AL 35660
419. George Y. Jordy, Director, Office of Program Analysis, Office of Energy Research, ER-30, C 226, U.S. Department of Energy, Washington, DC 20545

420. Sheldon Judson, Chairman, Department of Geological and Geophysical Sciences, Princeton University, Princeton, NJ 08540
421. Barclay Kamb, California Institute of Technology, Division of Geological and Planetary Science, Pasadena, CA 91225
422. Stephan Kempe, SCOPE/UNEP International Carbon Center, Hamburg University, Bundesstrasse 55, 2000 Hamburg 13, Federal Republic of Germany
423. H. Khalanski, EDF 6 quai Watier, 78400 Chatou, France
424. Hal Kibby, U.S.E.P.A. Environmental Research Laboratory, 200 S.W. 35th Street, Corvallis, OR 97330
425. Rennee Kirchmann, CEN/SIK, MOL, Belgium
426. Michael Kleinrock, Office of Environmental Audit and Compliance, EH-24, U.S. Department of Energy, 1000 Independence Ave., NW, Washington, DC 20585
427. William H. Koehler, Acting Dean, Graduate School, Texas Christian University, Fort Worth, TX 76129
428. V. A. Koonanoff, Director, Carbon Dioxide Research Division, Office of Health and Environmental Research, Office of Basic Energy Sciences, Code ER-12, Department of Energy, Washington, DC 20545
429. J. L. Kulp, Director of Research, National Acid Precipitation Assessment Program, 722 Jackson Place, NW, Washington, DC 20506
430. Frederick Kutz, U.S.E.P.A. Office of Research and Development, RD-682, 401 M St., SW, Washington, DC 20460
431. Robert T. Lackey, Environmental Protection Agency, Environmental Research Laboratory, 200 S. W. 35th Street, Corvallis, OR 97333
432. T. E. Langford, Central Electricity Research Laboratories, Freshwater Biology Unit, c/o Scientific Services Centre, Ratcliffe-on-Soar, Nottingham, NG 11 0EE, United Kingdom
433. Ted LaRoe, Chief, Division of Biological Services, U.S. Fish and Wildlife Service, Room 527, Matomic Bldg., Washington, DC 20240
434. George H. Lauff, W. K. Kellogg Biological Station, Michigan State University, Hickory Corners, MI 49060
435. J. A. Lenhard, Assistant Manager for Research & Development, Department of Energy, Oak Ridge Operations, Oak Ridge, TN 37831
436. S. A. Levin, Ecology and Systematics Department, Cornell University, Ithaca, NY 14850
437. R. A. Lewis, Lehrstuhl für Biogeographie, Universität des Saarlandes, D-6600, Saarbrücken, Federal Republic of Germany
438. C. S. Li, Department of Soil Science, University of Wisconsin, Madison, WI 53706
439. Library, Bureau of Sport Fisheries and Wildlife, Department of the Interior, Washington, DC 20240
440. Library, Food and Agriculture Organization of the United Nations, Fishery Resources and Environment Division, via delle Terme di Caracalla 001000, Rome, Italy
441. Library, Great Lakes Fishery Laboratory, U.S. Bureau of Sport Fisheries and Wildlife, Ann Arbor, MI 49904
442. G. S. Linsley, International Atomic Energy Agency, Wagsamerstrasse 5, P.O. Box 100, A-1400, Vienna, Austria
443. R. A. Linthurst, Environmental Protection Agency, MD-39, EPA/EH51 (Annex), Research Triangle Park, NC 27711
444. Ronald R. Loose, Acting Director, Office of Renewable Technology, Department of Energy, Washington, DC 20545
445. Orie L. Loucks, Holcomb Research Institute, Butler University, 4600 Sunset Ave., Indianapolis, IN 46208
446. A. E. Lugo, USDA/FS, P.O. Box AQ, Rio Piedras, PR 00928
447. Michael C. MacCracken, Atmospheric and Geophysical Sciences Division, Lawrence Livermore Laboratory, P.O. Box 808, Livermore, CA 94550
448. G. MacDonald, Metrek Division, Mitre Corporation, 1820 Dolly Madison Blvd., McLean, VA 22102
449. John Malanchuk, Acid Deposition Assessment Staff, U.S. Environmental Protection Agency, RD-676, 401 M St., SW, Washington, DC 20460
450. C. J. Mankin, Director, Oklahoma Geological Survey, The University of Oklahoma, 830 Van Vleet Oval, Room 163, Norman, OK 73019
451. Bernard Manowitz, Chairman, Department of Energy and Environment, Brookhaven National Laboratory, Upton, NY 11973
452. T. A. Mansfield, Department of Biological Sciences, University of Lancaster, Lancaster LA1 4YQ, Lancashire, England
453. John E. Matthews, U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, P.O. Box 1198, Ada, OK 74820
454. J. S. Mattice, Electric Power Research Institute, P.O. Box 10412, 3412 Hillview Ave., Palo Alto, CA 94303
455. Foster L. Mayer, Director, U.S.E.P.A. Environmental Research Laboratory, Sabine Island, Gulf Breeze, FL 32561
456. J. Richard Mayer, Dean, Huxley College of Environmental Studies, Western Washington University, Bellingham, WA 98225
457. Helen M. McCammon, Director, Ecological Research Division, Office of Health and Environmental Research, Office of Basic Energy Sciences, MS-E201, ER-75, Room E-233, Department of Energy, Washington, DC 20545
458. Thomas V. McEvilly, Chairman, Department of Geology and Geophysics, University of California, Berkeley, CA 94720
459. A. David McKinney, Tennessee Department of Health and Environment, 1522 Cherokee Trail, Knoxville, TN 37920
460. R. I. McLean, Administrator, Radioecological Assessments, Power Plant Siting Program, Maryland Department of Natural Resources, Towes State Office Bldg., Annapolis, MD 21401
461. J. S. McMahon, Atomic Energy of Canada Ltd., Biology and Health Physics Division, Chalk River Nuclear Laboratories, Chalk River, Ontario K0J 1J0, Canada
462. Ronald Menzel, Department of Agriculture, Water Quality and Watershed Research Laboratory, P.O. Box 1430, Durant, OK 74702
463. Jay Messer, U.S.E.P.A., Environmental Research Laboratory, Corvallis, OR 97330
464. Don Miller, Environmental Protection Agency, National Marine Water Quality Agency, South Ferry Road, Narragansett, RI 02882
465. Hugh G. Miller, The Macaulay Institute for Soil Research, Craigiebuckler, Aberdeen AB9 2QJ, Scotland
466. R. J. Millington, Division of Land Use Research, CSIRO, P.O. Box 109, Canberra City, ACT 2601, Australia
467. A. Alan Moghissi, Editor-in-Chief, Environment International, P.O. Box 7166, Alexandria, VA 22307
468. F. J. Molz, Department of Civil Engineering, Auburn University, Auburn, AL 36830
469. Harold A. Mooney, Department of Biological Sciences, Stanford University, Stanford, CA 94305
470. B. Moore III, Complex Systems Research Center, Science and Engineering Building, College Road, University of New Hampshire, Durham, NH 03824
471. Richard V. Moraski, U.S.E.P.A. Office of Research and Development, RD-689, 401 M St., SW, Washington, DC 20460
472. C. Myttenare, 200 Ren de la Soi, CEC Brussels, Belgium
473. J. Vincent Nabholz, Health and Environmental Review Division, Office of Toxic Substances, Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460
474. Director of Life Sciences Division, NASA, Federal Building No. 6, 600 Maryland Avenue, SW, Washington, DC 20546
475. National Library of Medicine, Serial Records Section, 8600 Rockville Pike, Bethesda, MD 20209
476. G. A. Neilson, Plant and Soil Science Department, Montana State University, Bozeman, MT 59717
477. Neal Newberger, House Office Building, 2217 Rayburn, Washington, DC 20515
478. L. Newman, Director, Atmospheric Sciences Division, Department of Energy and Environment, Brookhaven National Laboratory, Upton, Long Island, NY 11973
479. Joel O'Connor, NOAA Ocean Assessments Division, 11400 Rockville Pike, Rockville, MD 20852
480. Francisco de Assis Oliveira, Professor of Forest Ecology and Hydrology, Department of Silviculture, Faculty of Agrarian Sciences, PO Box 917, 66.000 Belem, para, Brazil
481. David M. Olszyk, Statewide Air Pollution Research Laboratory, University of California, Riverside, CA 92571
482. William S. Osburn, Jr., Ecological Research Division, Office of Health and Environmental Research, Office of Energy Research, Department of Energy, Washington, DC 20545
483. Constantine Papastefanou, Nuclear Physics Department, Aristotle University of Thessaloniki, Thessaloniki 540 06 Greece
484. V. L. Parker, Vanderbilt University, Nashville, TN 37240
485. John Peine, U.S. Department of the Interior, Uplands Field Research Laboratory, Twin Creeks Area, Great Smoky Mountains National Park, Gatlinburg, TN 37738
486. Carlos H. Pennington, Waterways Habitat and Monitoring Group, Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180
487. Ray Perry, Division of Land Resources Management, CSIRO, Private Bag, P.O. Wembley, Western Australia 6014, Australia
488. J. T. Peterson, GMCC/EKL/NOAA, 325 Broadway, Boulder, CO 80307 3000
489. Wolf Phil, Verein Deutscher Ingenieure, Grafecke Strasse 84, Postfach 1139, D-4000, Dusseldorf 1, Federal Republic of Germany
490. Charles W. Philpott, Department of Agriculture, Forest Service, FER-610, 12th and Independence Avenue, Washington, DC 20013
491. T. D. Placek, Department of Chemical Engineering, Auburn University, Auburn, AL 36830
492. D. Porcella, Electric Power Research Institute, P.O. Box 10412, Palo Alto, CA 94303
493. John Porter, Director, Environmental Sciences Section, Savannah River Laboratory, Aiken, SC 29801
494. A. Preston, Ministry of Agriculture, Fisheries and Food, Fisheries Radiobiological Laboratory, Hamilton Dock, Lowestoft, Suffolk, England
495. Richard Ragaini, Environmental Sciences Division, Lawrence Livermore Laboratory, P.O. Box 808, Livermore, CA 94550
496. J. C. Randolph, Indiana University, Environmental Programs, 400 East 7th Street, Room 438, Bloomington, IN 47401

497. Aino Rantavaara, Institute of Radiation Protection, Helsinki, Finland
 498. Oscar Ravera, Biology Division, C.C.R., Euratom, 21020 Centro Euratom di Ispra, Ispra, Varese, Italy
 499. William H. Regan, Jr., Division of Site Safety and Environmental Analysis, U.S. Nuclear Regulatory Commission, Washington, DC 20555
 500. Richard A. Reinert, Department of Plant Pathology, North Carolina State University, P.O. Box 5397, Raleigh, NC 27650
 501. Irwin Remson, Department of Applied Earth Sciences, Stanford University, Stanford, CA 94305
 502. Michael R. Riches, Carbon Dioxide Research Division, Office of Basic Energy Sciences, Code ER-12, U.S. Department of Energy, Washington, DC 20545
 503. Courtney Riordan, U.S. Environmental Protection Agency, Monitoring Systems and Quality Assurance, 401 M Street SW, RD-680, Washington, DC 20460
 504. Paul G. Risser, Vice President for Research, The University of New Mexico, Scholes Hall 108, Albuquerque, NM 87131
 505. Mike Roberts, Central Electricity Research Laboratories, Kelvin Avenue, Leatherhead, Surrey KT22 7SE, United Kingdom
 506. Andrew Robertson, Director, National Marine Pollution Control Program, N/MPP, 11400 Rockville Pike, Room 610, Rockwall Building, Rockville, MD 20852
 507. J. M. Robinson, Federal Energy Regulatory Commission, 825 North Capitol St., Washington, DC 20426
 508. Donald Rodier, Office of Toxic Substances, Environmental Review Division, Environmental Protection Agency, 401 M Street, SW, Washington, DC 20460
 509. C. E. Roessler, College of Engineering, Department of Environmental Engineering, University of Florida, Gainesville, FL 32601
 510. D. A. Sanders, U.S. Air Force, Occupational and Environmental Laboratory, Brooks Air Force Base, Texas 78235
 511. J. L. Sarmiento, Geophysical Fluid Dynamics Program, Princeton University, P.O. Box 308, Princeton, NJ 08542
 512. G. Saunders, Ecological Research Division, Office of Health and Environmental Research, Office of Energy Research, Department of Energy, Washington, DC 20545
 513. Ilkka Savolainen, Division of Nuclear Fuel Cycle, International Atomic Energy Agency, Wagramerstrasse 5, P.O. Box 100, A-1400, Vienna, Austria
 514. Vincent Schultz, Department of Zoology, Washington State University, Pullman, WA 99164
 515. J. Schwibach, Federal Health Office, 8042 Neuherberg bei Munchen, Ingolstadter Landstr. 1, Federal Republic of Germany
 516. Hans Martin Seip, Central Institute for Industrial Research, Royal Norwegian Council for Scientific and Industrial Research, Forskningsv. 1, P.O. Box 350, Blindern, Oslo 3, Norway
 517. Roger Shull, Division of Environmental Impacts, Department of Energy, Washington, DC 20545
 518. D. L. Shumway, Federal Energy Regulatory Commission, 825 North Capitol St., Washington, DC 20426
 519. Katie Siering, Department of Ecology, Ethology, and Evolution, University of Illinois, Urbana, IL 61801
 520. David H. Slade, Pollutant Characterization & Safety Research Division, Department of Energy, Washington, DC 20545
 521. H. Smith, National Radiological Protection Board, Building 566, Harwell, Didcot, Oxfordshire OX11 0RQ, England
 522. Michael Smith, Savannah River Ecology Laboratory, E. I. duPont Company, Aiken, SC 29801
 523. R. J. Stern, Director, Office of Environmental Compliance, MS PE-25, FORRESTAL, U.S. Department of Energy, 1000 Independence Avenue, SW, Washington, DC 20585
 524. B. R. Strain, Department of Botany, Duke University, Durham, NC 27708
 525. M. Stuiver, Isotope Laboratory, Department of Geological Sciences, AK-60, University of Washington, Seattle, WA 98195
 526. Kevin Sullivan, Director, Chesapeake Bay Center for Environmental Studies, Route 4, Box 262, Edgewater, MD 21037
 527. Wayne T. Swank, Coweeta Hydrologic Laboratory, U.S. Forest Service, Franklin, NC 28734
 528. W. L. Templeton, Ecosystems Department, Battelle-Pacific Northwest Laboratory, Richland, WA 99352
 529. S. E. Thomas, Assistant General Manager, Bowater Southern Paper Company, Calhoun, TN 37309
 530. University of Tennessee Center for the Health Sciences Library, 800 Madison Ave., Memphis, TN 38163
 531. Mike Unsworth, Institute of Terrestrial Ecology, Edinburgh Research Station, Bush Estate, Penicuik, Midlothian EH26 0QB, Scotland
 532. Burt Vaughan, Battelle-Pacific Northwest Laboratory, Richland, WA 99352
 533. Herbert L. Volchok, Director, Environmental Measurements Laboratory, Department of Energy, 376 Hudson Street, New York, NY 10014
 534. Donald E. Walsh, Associate Director of University Research, The University of Mississippi, University, MS 38677
 535. Donald K. Walters, Biofuels and Municipal Waste Technology Division, Department of Energy, MS-CE341, Forrestal Building, 1000 Independence Avenue, SW, Washington, DC 20585
 536. Walter L. Warnick, U.S. Department of Energy, Program Integration Analysis Division, Office of Energy Research, ER-32, G-226, Washington, DC 20545
 537. Robert L. Watters, Ecological Research Division, Office of Health and Environmental Research, Office of Energy Research, Department of Energy, Washington, DC 20545
 538. Leonard H. Weinstein, Program Director of Environmental Biology, Cornell University, Boyce Thompson Institute for Plant Research, Ithaca, NY 14853
 539. C. Whittle, Oak Ridge Associated Universities, Institute of Energy Analysis, Oak Ridge, TN 37831
 540. James G. Wiener, U.S. Fish and Wildlife Service, P.O. Box 936, LaCrosse, WI 54601
 541. T. M. L. Wigley, Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, England
 542. Raymond G. Wilhour, Chief, Air Pollution Effects Branch, Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency, 200 SW 35th Street, Corvallis, OR 97330
 543. Ted Williams, U.S. Department of Energy, Office of Environmental Analysis, 1000 Independence Avenue SW, Forrestal Building, PE-26, Room 4G 036, Washington, DC 20585
 544. M. M. Williamson, Director, Radiological and Environmental Sciences Laboratory, Department of Energy, Idaho Operations Office, 550 2nd Street, Idaho Falls, ID 83401
 545. J. L. Wilson, Department of Forestry, Wildlife and Fisheries, P.O. Box 1071, University of Tennessee, Knoxville, TN 37901
 546. Frank J. Wobber, Ecological Research Division, Office of Health and Environmental Research, Office of Energy Research, MS-E201, Department of Energy, Washington, DC 20545
 547. M. Gordon Wolman, The Johns Hopkins University, Department of Geography and Environmental Engineering, Baltimore, MD 21218
 548. Robert W. Wood, Director, Division of Pollutant Characterization and Safety Research, Department of Energy, Washington, DC 20545
 549. James N. Woodman, Champion International, One Champion Plaza, Stamford, CT 06921
 550. Robert Woodmansee, Natural Resources Ecology Laboratory, Colorado State University, Fort Collins, CO 80523
 551. G. M. Woodwell, Woods Hole Research Center, P.O. Box 296, Woods Hole, MA 02543
 552. M. Wunderlich, Bundesanstalt fur Gewasserkunde, Federal Institute for Water Studies, Koblenz, Federal Republic of Germany
 553. Larry Zaragoza, MD-12, Environmental Protection Agency, Research Triangle Park, NC 27711
- 554-752. Given distribution as shown in DOE/TIC 4500 under category UC-11, Environmental Control Technology and Earth Sciences

DATE ISSUED

APR 25 1985

2568



ORNL-6140

**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

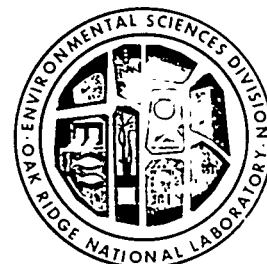
**Environmental Sciences Division
Annual Progress Report
for Period Ending September 30, 1984**

**Environmental Sciences Division
Publication No. 2454**

ChemRisk Document No. 2568

This document has been approved for release
to the public by

Dwight Harrison 2/9/96
Technical Information Officer Date
ORNL Site



OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A10 Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL-6140
Distribution Category UC-11

ENVIRONMENTAL SCIENCES DIVISION
ANNUAL PROGRESS REPORT
for Period Ending September 30, 1984

S. I. Auerbach, Director
D. E. Reichle, Associate Director

Environmental Sciences Division Publication No. 2454

Date Published: April 1985

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

ABSTRACT

AUERBACH, S. I., et al. 1985. Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1984. ORNL-6140. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 216 pp.

The principal objectives of the Environmental Sciences Division (ESD) of Oak Ridge National Laboratory (ORNL) are to conduct research on the environmental aspects of existing and emerging energy systems and to utilize this information to ensure that technology development is consistent with national environmental health and safety goals. ESD performs basic and applied research, environmental assessments, environmental engineering and demonstration, technology and operational support, and program management for the U.S. Department of Energy (DOE), other federal and state agencies, and industry. ESD works collaboratively with a number of federal agencies, universities, and the private sector in accomplishing its programs. The Division offers an interdisciplinary resource of staff and facilities to address complex environmental problems. ESD is currently providing technical leadership for four major environmental issues of national concern: acidic deposition and related environmental effects, the global carbon cycle and CO₂-induced climatic effects on ecosystems, hazardous chemical and radioactive waste disposal R&D, and development of commercial biomass energy production systems. This progress report outlines ESD's accomplishments in these and other energy support areas for FY 1984.

ESD has a major role in research on and assessment of the effects of acidic deposition as a part of the National Acid Precipitation Assessment Program. The Division's long history of research on ecosystem processes has resulted in its staff scientists playing leading roles in research efforts related to both terrestrial and aquatic ecosystem responses to acidic deposition. Support for acidic deposition research and assessment activities in the Division is broad based, including DOE, the U.S. Environmental Protection Agency, and the Electric Power Research Institute.

Research in the Aquatic Ecology Section emphasizes development of a scientific basis for evaluating the effects of energy technologies on freshwater ecosystems. In FY 1984 research focused on the ecological processes regulating the cycling of nutrients and contaminants in streams and reservoirs. Work continued on a multiyear study on the effect of acid precipitation on the mobilization of aluminum and its transport in streams. Studies were initiated to document the efficacy of a series of remedial actions being undertaken to improve environmental quality in Bear Creek Valley on the Oak Ridge Reservation.

Environmental research and engineering activities of the Earth Sciences Section in support of DOE's Oak Ridge facilities expanded during FY 1984 as significant increases in ESD participation at the Y-12 Plant occurred. In addition, programs supporting ORNL in radioactive waste management strategy and operations continued with efforts toward the possible opening of two disposal areas and corrective measures for older areas. Construction has been completed on two subsurface weirs that will be used to study the movement of groundwater and transport of contaminants in macropores and as interflow. These facilities will provide a new opportunity to obtain data on the spatial and temporal variations that appear to dominate the flow of groundwater in the unsaturated zone in many regions. The dominant role of atmospheric deposition in supplying several trace materials to forests was established through a program of direct measurement. The results highlight the importance of atmospheric deposition not only for possible contamination of forests but also for their nutrient supplies.

Major activities of the Environmental Analyses Section this year included technical analyses of the environmental consequences of hydroelectric development, nuclear waste disposal, aqueous and airborne chemical effluents, and acidic deposition. Highlights include (1) management and analysis of national data sets developed to assess the impacts of acidic deposition, (2) completion of a major study of the applicability of aquatic habitat evaluation models in southern Appalachian trout streams, (3) development of impact analyses of proposed hydroelectric development in Alaska and California, (4) development of new approaches to quantify landscape patterns, and (5) technical review of analyses developed to select repository sites for high-level nuclear waste under the Nuclear Waste Policy Act.

Research activities in the Terrestrial Ecology Section are focusing on major environmental concerns associated with acid precipitation, global carbon, renewable energy systems, and transport of trace contaminants in terrestrial systems. Recent activities in these areas include utilizing tree rings for detecting anthropogenic stress, simulating forest growth and development in response to such stress, and establishing terrestrial pathways of radionuclides and organic contaminants.

The research activities of the DOE-sponsored Biomass Production Program have been consolidated in ESD. Approximately 75% of this work was subcontracted research that focused on R&D on herbaceous and woody plants as potential energy crops, with strong components in genetics, cultural techniques, and economic evaluation. The remaining work involves in-house activities that concentrate on program management, site-specific nutrient and environmental studies, and regional resource and economic assessments, all of which more clearly identify the potentials and concerns associated with growing biomass for energy.

The DOE Global Carbon Cycle Program continued to provide direct assistance to DOE's Carbon Dioxide Research Division in (1) monitoring the progress of ORNL subcontracts, DOE contracts, and in-house projects; (2) identifying research needs to support global carbon cycle model development; and (3) recommending methods for fulfilling these needs. Research in FY 1984 continued to improve our understanding of the terrestrial component of the carbon cycle, and support for oceanic research, including measurement programs and three-dimensional modeling, was substantially expanded. An additional activity this past year involved the drafting of a DOE state-of-the-art report on global carbon cycle research, with contributions from an international team of authors and reviewers.

Contents

ABSTRACT	iii
ENVIRONMENTAL SCIENCES DIVISION AWARDS AND HONORS	xi

PART I. NEW INITIATIVE

1. ACIDIC DEPOSITION	1
Introduction	1
Watershed Nutrient Dynamics	1
Air Pollution and Forest Growth	2
Interactions Between the Forest Canopy and the Atmosphere	3
Effects on Aquatic Ecosystems	3
Acidic Deposition Assessment	4
Conclusions	4

PART II. ENVIRONMENTAL SCIENCES DIVISION SECTIONS

2. AQUATIC ECOLOGY	6
Introduction	6
Biogeochemical Cycling	8
Effects of Acidification on Woodland Stream Ecosystems	8
Environmental, Physiological, and Molecular Mechanisms Controlling Food Chain Transfer of Organic Contaminants in Aquatic Systems	12
Ecological Effects (Aquatic Toxicology)	13
Long-Term Effects of Organic Contaminants in Aquatic Ecosystems	13
Lake Acidification and Fisheries	13
Modeling the Effects of Chemicals in Aquatic Systems	14
Biochemical and Physiological Indicators of Acidification Stress in Fish	15
Legionnaires' Disease Bacteria in Power Plant Cooling Waters	15
Ecosystem Dynamics	17
Reservoir Studies	17
Further Research with the Fates of Aromatics Model	19
Reservation Studies	20
Ecological Studies Associated with Implementation of Improved Waste Management Operations in Bear Creek Valley	20
Aquatic Toxicity of Y-12 Cooling Tower Effluents	21

3. EARTH SCIENCES	22
Introduction	22
Low-Level Radioactive Waste Research and Development Program	23
Solid Waste Storage Area 4 Studies	23
Characterization of Solid Waste Storage Area 6	23
Radioactive Gas Production at Solid Waste Storage Area 6	24
Status of Liquid Low-Level Waste Pits and Trenches	24
Long-Term Vegetation Management Studies	24
Hydrologic Characterization of Proposed Solid Waste Storage Area 7	25
Characterization of the Surface Water Hydrology at the Proposed Central Waste Disposal Facility	25
Shallow Land Burial Technology—Humid	25
Corrective-Measures Technology for Humid Sites	26
Engineering Demonstration of In Situ Grouting at Maxey Flats	26
Chemical Waste Research and Development	27
A Laboratory Extraction Method to Simulate Codisposal	27
Leaching Characteristics of Resource Recovery Ash	27
Sulfur Waste Management	28
Codisposal of Solid Wastes from Coal Synfuel Facilities	29
Subsurface Transport Program	29
Field Studies	29
Laboratory Studies	30
Modeling Activities	30
Hydrology	31
Hydrology of Bear Creek	31
Remote Sensing	32
Water-Budget Evaluations	32
Model Development	33
Geology and Geochemistry	33
Sedimentary Rock Program	33
The Hydrofracture Facility	33
Geochemistry of High-Level Radioactive Waste Repositories	34
Geologic Research in Bear Creek Valley	35
Investigation of Subsurface Mercury at the Oak Ridge Y-12 Plant	35
Environmental Engineering and Management	35

Design and Construction of a Groundwater Barrier in Solid Waste Storage Area 6	35
Risk Analysis of Transporting Army Chemical Warfare Munitions	37
DOE National Hazardous Waste Program	37
Environmental Chemistry	38
Contribution of Atmospheric Particles and Vapors to Deposition and Element Cycling in a Forest	38
Radionuclides and Trace Species in River-Estuarine and Coastal Environments	38
Characterization of Radionuclide-Contaminated Soils from the Sedan Area at the Nevada Test Site	39
Evaluation of Radionuclide Mobilization at the NRC-Licensed Disposal Area at West Valley, New York	39
References	39
4. ENVIRONMENTAL ANALYSES	41
Introduction	41
Selection of High-Level Waste Repository Sites	43
Environmental Impacts Associated with Demilitarization of Nerve Gas Rockets	44
The Susitna Hydroelectric Project	44
San Joaquin River Basin Study	45
Structure-Toxicity Relationships for Synfuels Risk Analysis	46
Assessing Streamflows for the Protection of Fishery Resources: A Field Evaluation of Existing Methods in Southern Appalachian Trout Streams	47
Assessment of Research on Residual Ecological Problems of Contaminated Land Areas	48
Characterization of Water Quality and Quantity for a National Assessment	49
Landscape Pattern and Systems Analysis	51
Biophysical Regions of Influence	51
Acid Deposition Data Network	53
National Surface Water Survey	54
References	54
5. TERRESTRIAL ECOLOGY	55
Introduction	55
Ecosystem Dynamics	57
Potential Direct and Indirect Effects of Elevated Levels of Atmospheric CO ₂ on Forest Community Biomass	57
Assessment of Climate Model Simulations for Use in Investigating Potential Impacts of Climatic Change	58

Use of X-Ray Densitometry to Analyze the Effects of Elevated Atmospheric CO ₂ on Tree Growth	58
Physiological Ecology	59
Dendroecological Analysis of Forest Growth Responses	59
Responses of Two Forest Tree Species and Their Associated Root Microflora to Elevated Levels of Atmospheric CO ₂	61
Uptake, Translocation, and Metabolism of Polycyclic Aromatic Hydrocarbons in Plants	62
Biogeochemical Cycling	63
Synthesis of Nutrient Cycling Studies on Walker Branch Watershed	63
Applications of Natural Radioactivity for Increasing Our Understanding of Environmental Processes: Dry Deposition of Submicron Aerosols	64
Rates of Dry Deposition and Foliar Leaching Determined by Analysis of Throughfall	66
Long-Term Fate of Technetium-99 in Forest Environments	68
Terrestrial Ecosystems, Climate, and the Global Carbon Cycle	69
References	70

PART III. ENVIRONMENTAL SCIENCES DIVISION PROGRAMS

6. BIOMASS PRODUCTION	71
Introduction	71
Herbaceous Energy Crops Program	72
Sugar and Starch Crops	73
Oilseed Crops	73
Hydrocarbon Crops	74
Lignocellulosic Crops	74
Short Rotation Woody Crops Program	75
Program Management	76
Economic Analysis	76
Species Selection	77
Biological Evaluation of Crop Management Alternatives	78
Conclusions and Recommendations	79
Environment and Analysis Program	79
Resource Assessment	79
Economic Analyses	80
Nutrient Conservation/Productivity Studies	82
References	83

7. DEPARTMENT OF ENERGY GLOBAL CARBON CYCLE PROGRAM	84
Introduction	84
Extramural Research	86
Deforestation in the Amazon Basin Measured by Satellite Imagery	86
Mathematical Models for Use in Defining the Role of the Terrestrial Biota in the Global CO ₂ Cycle	87
Land-Use and Vegetation Changes in South and Southeast Asia	88
Response of Soil Carbon to Land-Use Change in the Tropics	89
Development of a Three-Dimensional Model of the Natural Carbon Cycle in the Ocean and Its Perturbation by Anthropogenic CO ₂	90
Study of CO ₂ Source and Sink Distributions with a Three-Dimensional Model	90
Intramural Research	91
Effects of Agriculture on Soil Carbon	91
Influence of Climate, Soil Moisture, and Succession on Carbon and Nitrogen Cycles in Forests	92
Reconstructing Land-Use Patterns and the History of Terrestrial Carbon Storage	93
Modeling Global Seasonal Carbon Fluxes	94
A Two-Dimensional CO ₂ -Ocean Model Including the Biological Processes	94
Effect of Ocean Life Cycles on the Atmospheric CO ₂ Content	95
Estimating Uncertainties of Predicted Carbon Emissions 1975–2075	95
References	96

PART IV. EXTRAMURAL ACTIVITIES

8. EDUCATIONAL ACTIVITIES	98
Seminar Program	98
Graduate Education Program	98
Undergraduate Education Program	99
9. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS	101

PART V. APPENDICES

PUBLICATIONS, PRESENTATIONS, THESES, AND PROFESSIONAL ACTIVITIES...	112
Publications	112
Presentations	137
Theses	158

Professional Activities	159
ORGANIZATION CHART	184